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(54) Method of and device for determining the relative positions of a plurality of objects

Verfahren und Vorrichtung zum Bestimmen der relativen Position mehrerer Objekte

Procédé et dispositif pour déterminer la position relative de plusieurs objects

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(56) References cited:
EP-A- 0 039 143
EP-A- 0 266 525
FR-A- 2 519 138
FR-A- 2 620 818

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Description

The present invention relates to a method of and a device for measuring in two or three dimensions and without contact the position accuracy of mechanical components after assembly such as, for example, mechanisms of drums, posts and the like of video tape recorders (hereafter abbreviated as VTRs).

In recent years, in VTRs, efforts have been made to improve the accuracy of mechanisms for high-density recording. Also, in order to achieve compatibility between systems, the technology for the high-accuracy measurement of the position of components becomes important to minimize variations between decks.

Explained below is a conventional method of measuring the position accuracy of components related to VTRs after assembly.

First, the mechanism of a VTR to be measured will be explained. A rotary drum performs recording or playback by means of a magnetic rotary head mounted at the bottom end thereof, with a magnetic tape, supplied from a cassette, wound diagonally around the rotary drum. The magnetic tape is not to be run during the measurement. A stationary drum has a stepped or shoulder portion known as a lead which regulates the bottom edge of the magnetic tape. The rotary drum and the stationary drum constitute a drum unit. A roller post positioned upstream of the drum unit with respect to the direction of motion of the magnetic tape stands vertically and regulates the upper-edge of the magnetic tape in motion, and an inclined post changes the direction of motion of the magnetic tape. These posts are hereinafter referred to as upstream posts. An inclined post positioned downstream of the drum unit with respect to the direction of motion of the magnetic tape restores the motion of the magnetic tape to its original direction, and a roller post stands vertically and regulates the upper edge of the magnetic tape. These posts are hereinafter referred to as downstream posts. Thus, the measurement object (object to be measured) in this example comprises the drum unit, roller posts, and inclined posts, all of which are regarded as the main components of the VTR mechanism.

Next, a conventional, contact-type device for measuring position coordinates will be explained. First, a measurement object is set on a reference plane of a measurement platform. A probe which is affixed to the contact-type device for measuring position coordinates is capable of moving in X, Y and Z directions. Also, each of the X, Y and Z coordinates is detected by a position coordinate detection device. A computation device computes the position coordinates in X, Y and Z directions from the values that have been detected by the position coordinate detection device, and computes the angle of inclination and the direction of inclination of the measurement object and the distance between the centers of the posts.

With regard to the conventional contact-type position coordinate measurement device configured in the above manner, its measurement method will be explained below.

First, the method of measuring the upstream inclined post will be explained. Set the reference directions, X and Y, and set, for instance, the center of the moving magnetic tape as the reference height of the mechanism. Next, at an arbitrary height, let the probe contact the outer periphery of the inclined post at a minimum of 3 points, find the X, Y coordinates, and from those values find the center of the post. Similarly, take measurements at a different height, and find the center of the post. In effect, by taking measurements at arbitrary heights at a minimum of two places, a center line connecting the coordinates of the centers of the inclined post can be found. Similarly, a center line of the upstream roller post can be found.

In this way, all of the inclination angles, inclination directions and x, y coordinates at arbitrary heights of the inclined posts, and the distance between the centers of the posts at the reference height can be found by computation with the computation device.

However, as explained below, there are problems with the aforementioned conventional setup:

(1) Since the rotary drum is a rotating body, it is difficult to bring the probe into contact therewith when the rotary drum is rotating. Accordingly, no measurement can be made during rotation and, hence, no measurement can be made of the relative position between the drum unit and other posts, which is the most important measurement.
(2) Since the inclined post is inclined at an angle, the probe can be brought into contact with only a limited portion thereof in obtaining the center thereof. Hence, errors are likely to occur when the center of the circle is obtained. Furthermore, the larger the angle of inclination, the larger this trend becomes. Also, the distance between the inclined post and the roller post is very narrow, and is expected to become even narrower as miniaturization of the mechanism continues further in the future, so that the measurement portion will be further restricted.
(3) A post that is small in diameter and low in stiffness will change its shape when a load is applied due to probe contact, and therefore accurate measurement cannot be made.
(4) Contact-type measurement cannot be made when a magnetic tape is wound around the measurement object. However, when recording or playback is actually done, a force is applied to the measurement object, since the magnetic tape is wound therearound with a constant tension. Hence, delicate differences will occur in measurements of assembling accuracy of the mechanism depending on whether the magnetic tape is present or not.
(5) The device is large in size.

Therefore, it was not considered to be a method which would enable measurement of the positions of the components of the assembled mechanism.

The present invention has been developed to overcome the above-described disadvantages.

It is accordingly an objective of the present invention to provide a method of and a device for measuring without contact two-dimensional or three-dimensional position coordinates of the components of a mechanism after assembly.

Non-contact measuring equipment is known in general. EP-A-0,039,143 discloses a system in which a plurality of beams of electromagnetic radiation are directed towards one object, in particular an exhaust pipe, and the radiation not blocked by the object is detected. From this detection radiation, the outer shape of the object can be determined.

According to a first aspect of the present invention, a method for determining the relative positions of a plurality of objects comprises the steps of

(a) placing the plurality of objects to be measured on a plane;
(b) irradiating a laser beam on said plurality of objects from a plurality of different directions while said laser beam is being moved in a direction generally perpendicular to said plane, said laser beam having a predetermined diameter and scanning parallel to said plane;
(c) computing a plurality of different projected position coordinates of said plurality of objects from two tangent points of a cross-section which is generated when said plurality of objects are cut with said laser beam; and
(d) computing three-dimensional position coordinates of said plurality of objects and distances between said plurality of objects, from said different projected coordinates, the angular difference between said different directions, and the length of movement of said laser beam.

According to a second aspect of the present invention, a device for determining the relative positions of a plurality of objects comprises

a plane on which a plurality of objects to be measured is placed;
a light emitting optical system for emitting a laser beam having a predetermined diameter and scanning parallel to said plane;
a light receiving optical system having a photodetector for detecting said laser beam;
a drive means for moving one of said plurality of objects and said light emitting and receiving optical systems relative to each other so that said plurality of objects are irradiated with a laser beam at a plurality of heights;
a movement detection means for detecting the length of movement of said one of said plurality of objects and said light emitting and receiving optical systems
a rotating means for rotating one of said plurality of objects and said light emitting and receiving optical systems relative to each other to thereby change an angle by which said plurality of objects are irradiated;
a rotational angle detection means for detecting the angle of rotation of said one of said plurality of objects and said light emitting and receiving optical systems
a computation means for determining a plurality of different projected coordinates of said plurality of objects from outputs of said photodetector by irradiating the objects from a plurality of different directions; and
a computation processing means for determining three-dimensional position coordinates of said plurality of objects and distances between said plurality of objects from said different projection position coordinates of said plurality of objects, said angle of rotation, and said length of movement.

By the above-described construction, the relative positions of, for example, assembled components can be measured at a high accuracy and high speed without contact regardless of the attitude or size thereof.

Preferably, the object is in contact with a transparent tape, which allows the laser beam to transmit therethrough, and a tension is applied to the tape by a tension device.

By so doing, the two-dimensional position coordinates can be measured in a condition in which the tension is applied to the tape.

Also, preferably, the tape is moved relative to the object by a tape drive means. In this case, the two-dimensional position coordinates of the assembled components can be measured in a condition in which the tape is running, i.e., the condition unlimitedly close to the actual recording or playback mode.

In order to carry out the method of claims 1 to 4, plural sets of light emitting and receiving optical systems disposed on opposite sides of the object may be provided. The plural sets of light emitting and receiving optical systems are spaced a predetermined angle from each other.

In this case, rotating means and rotational angle detection means are not required. The computation means determines the different projected position coordinates of the object from outputs of photodetectors of the plural sets of light emitting and receiving optical systems, and the computation processing means determines the two-dimensional position coordinates of the object from the different projected position coordinates of the object and the angular difference in the position of the plural sets of light-emitting and receiving optical systems.

The above and other objectives and features of the

present invention will become more apparent from the following description of preferred embodiments thereof with reference to the accompanying drawings, throughout which like parts are designated by like reference numerals, and wherein:

Fig. 1 is a perspective view of a position coordinate measurement device according to a first embodiment of the present invention;
Fig. 2 is a schematic block diagram indicating the system construction of Fig. 1;
Fig. 3 is a perspective view of an object to be measured during measurement;
Fig. 4 is a perspective view of a roller post and an inclined post of the object of Fig. 3;
Fig. 5 is a view similar to Fig. 4, but indicating the two posts when the object of Fig. 3 is rotated;
Fig. 6 is a view similar to Fig. 5, but indicating the relative positional relationship between the two posts;
Fig. 7 is a perspective view of the object of Fig. 3 when measured by the position coordinate measurement device having a tension device;
Fig. 8 is a view similar to Fig. 4, but indicating the two posts when a tension is applied thereto by the tension device through a transparent tape wound therearound;
Fig. 9 is a view similar to Fig. 8, but indicating the two posts when the object is rotated;
Fig. 10 is a perspective view of the object when measured by the position coordinate measurement device having a tension device and a tape drive;
Fig. 11 is a perspective view of a position coordinate measurement device according to a second embodiment of the present invention;
Fig. 12 is a perspective view of a position coordinate measurement device according to a third embodiment of the present invention;
Fig. 13 is a schematic block diagram indicating the system construction of Fig. 12;
Fig. 14 is a perspective view of the object when measured by the device of Fig. 12;
Fig. 15 is a perspective view of a roller post and an inclined post of the object of Fig. 14;
Fig. 16 is a view similar to Fig. 15, but indicating the two posts when the object of Fig. 14 is rotated;
Fig. 17 is a view similar to Fig. 16, but indicating the relative positional relationship between the two posts;
Fig. 18 is a perspective view of two reference posts for use in setting the reference height;
Fig. 19 is a perspective view of the object of Fig. 14 when measured by the position coordinate measurement device having a tension device;
Fig. 20 is a view similar to Fig. 15, but indicating the two posts when a tension is applied thereto by the tension device through a transparent tape wound therearound;
Fig. 21 is a view similar to Fig. 20, but indicating the two posts when the object is rotated;
Fig. 22 is a perspective view of the object when measured by the position coordinate measurement device having a tension device and a tape drive; and
Fig. 23 is a perspective view of a position coordinate measurement device according to a fourth embodiment of the present invention.

A position coordinate measurement device of the present invention for finding two- or three-dimensional position coordinates will be discussed hereinafter with reference to the drawings.

Fig. 1 depicts a position coordinate measurement device according to a first embodiment of the present invention.

In Fig. 1, a measurement object 70 is installed or placed on an installation plane 39 of a measurement platform 38 having a rotary stage 33. A light emitting optical system 15 and a light receiving optical system 21 are disposed on opposite sides of the measurement platform 38. The light emitting optical system 15 comprises a scanning mirror 17 such as a polygon mirror to scan a laser beam 14, an fθ lens 18 for focusing the laser beam 14 that has been scanned by the scanning mirror 17 to a predetermined beam diameter, and also for scanning the laser beam parallel to the installation plane 39, and a cover 19. The light receiving optical system 21 comprises a focusing lens 22 for focusing part of the laser beam 14 that is not intercepted by the measurement object 70, a photodetector 23 placed at a focal point of the focusing lens 22 to output High and Low signals alternately in response to the brightness and darkness of the light, and a cover 24. The rotary stage 33 rotates the measurement object 70 about the Z axis, and a rotational angle detection device 34, a photoelectric rotary encoder for example, detects the rotational angle (γ).

In Fig. 2, a computation device 49 compares the time t (t1, t2, t3, ...) at which the photodetector 23 outputs alternate signals of High and Low with a pulse signal generated in synchronism with the rotation of the scanning mirror 17, and converts the results to X-projected position coordinates (x1, x2, x3, ...). A computation processing device 50 computes the center distance (L) of the measurement object 70 shown in Fig. 6, based on the rotational angle (γ) and the X-projected position coordinates (x1, x2, x3, ...).

Next, the measurement object 70 will be discussed with reference to Fig. 3 indicating mechanical components of a VTR.

As is well known to those skilled in the art, the VTR generally includes a plurality of posts disposed upstream and downstream of a drum unit with respect to the direction of motion of a magnetic tape. Hence, for the purpose of discussion of various preferred embodiments of the present invention, the measurement object

70 is described as having upstream posts and downstream posts, these terms "upstream" and "downstream" being used in relation to the direction of motion of the magnetic tape.

In Fig. 3, a rotary drum 1 performs recording or playback by means of a magnetic head 2 mounted on the bottom end thereof, in a condition in which a magnetic tape supplied from a cassette (not shown) is wound diagonally around the rotary drum 1. It is, however, to be noted that the magnetic tape is not to be run during actual measurement. A stationary drum 3 has a lead 4 which regulates the lower edge of the magnetic tape. The rotary drum 1 and stationary drum 3 constitute a drum unit 5. An upstream roller post 6, which stands vertically, regulates the upper edge of the magnetic tape in motion, and an inclined post 7 changes the direction of motion of the magnetic tape. A downstream inclined post 8 restores the motion of magnetic tape 13 to its original direction, and a roller post 9, which stands vertically, regulates the upper edge of the magnetic tape. Thus, the measurement object 70 in this preferred embodiment comprises elements 1 through 9 which are the principal parts of the VTR mechanism. The roller post 6 and inclined post 7 are retained by an upstream base 10, while the roller post 8 and inclined post 9 are retained by a downstream base 11. These bases 10 and 11 are mounted on a chassis 12 along with the drum unit 5.

The two-dimensional position coordinate measurement device configured as described above is discussed hereinafter, taking a measurement method for the upstream roller post 6, inclined post 7 and drum unit 5 as example.

In Fig. 3, the measurement platform 38 is rotated by means of the rotary stage 33 so that the upstream roller post 6, inclined post 7 and drum unit 5 can be measured. At this moment, dark portions appear on the light receiving side if the laser beam 14 is intercepted by the measurement object 70, and bright portions appear if the laser beam 14 is not intercepted. As a result, light boundaries (a) through (h) are generated in the X-axis direction. Of these light boundaries (a) through (h), (b) and (c) indicate the boundaries for the roller post 6, while (d) and (e) indicate the boundaries for the inclined post 7.

More specifically, the laser beam 14 is irradiated on the upstream roller post 6 and inclined post 7 at the reference height (Z=0) shown in Fig. 4. With respect to the inclined post 7, the first X-projected position coordinates (S0, T0), which are the light boundaries (d) and (e) in the X-axis direction as explained above, are computed with the computation device 49 from both tangent points P0 and Q0 of a cross-sectional circle D0, which is generated when the inclined post 7 is cut by the laser beam 14. Next, in Fig. 5 wherein the measurement platform 38 is rotated by means of the rotary stage 33 by an angle of (γ) from the state of Fig. 4, the laser beam 14 is irradiated on the inclined post 7 and roller post 6 from an angle differing by the angle of (γ). Then, from both tangent points PP0 and QQ0 of the cross-sectional circle, which is generated when the inclined post 7 is cut by the laser beam 14, the second X-projected position coordinates (SS0, TT0) are found with the computation device 49. Then, from the first X-projected position coordinates (S0, T0) and the second X-projected position coordinates (SS0, TT0), the X-projected position coordinates (U0, UU0) of the center of the inclined post 7 as seen from both the directions are calculated in approximation with the computation processing device 50. Similarly, the X-projected position coordinates (W0, WW0) of the center of the roller post 6 as seen from both the directions can also be found. Hence, in Fig. 6, the center distance (L) at the reference height (Z=0) between the upstream inclined post 7 and roller post 6 can be found from the X-direction distance (Lx), Y-direction distance (Ly) and the difference in rotational angle (γ) using Formula 1 represented by:

$$L=\sqrt{Lx^2 + Ly^2}$$

where $Lx=U0-W0$ and $Ly=\{(U0-W0)-(UU0-WW0)/\cos\gamma\}/\tan\gamma$.

Similarly, the center distance (L) between the roller post 6 and drum unit 5 or between the inclined post 7 and drum unit 5 can be found. Also, the drum unit 5, the downstream inclined post 8 and roller post 9 can be measured by rotating them until profile lines thereof are detected by the light receiving optical system.

As described above, according to this preferred embodiment, a non-contact measurement of all center distances (Ls) is possible at an arbitrary height for the upstream roller post 6, inclined post 7, drum unit 5, downstream inclined post 8 and roller post 9.

Note that in this embodiment, an explanation was given concerning the method of and the device for finding the two-dimensional position coordinates from two sets of different X-projected position coordinates obtained by rotating the measurement object, but conversely, measurement can be made similarly by rotating the light emitting optical system and light receiving optical system relative to the measurement object. Furthermore, in this embodiment, an explanation was given concerning the case of irradiating the laser beam from two different directions, but since the two-dimensional position coordinates can be determined by obtaining at least two sets of different X-projected position coordinates, measurement can be made from three or more directions, and in that case, the measurement accuracy would improve further.

As shown in Fig. 7, a tension device 60 may be mounted on the chassis 12 to provide a tape 73 with a constant tension. The tension device 60 comprises a tension post 61 which makes contact with the tape 73, a base 62 for retaining the tension post 61, and a spring 63 having one end connected to the chassis 12 and the other end connected to the base 62. In this case, the

measurement object 70 comprises the principal components 1 through 9 of the VTR mechanism and the tension device 60. The tape 73, wound around the measurement object 70 with a fixed angle, is a transparent tape such as, for example, a base film on which no magnetic substance is coated so that it transmits the laser beam 14 therethrough and has approximately the equivalent properties of, e.g., thickness and stiffness, with those of the magnetic tape for use in recording signals.

The two-dimensional position coordinate measurement device configured as described above is discussed hereinafter, taking a measurement method for the upstream roller post 6, inclined post 7 and drum unit 5 as example.

The tape 73 is first wound around individual components of the measurement object 70, and a constant tension is applied thereto by means of the tension device 60. Next, the measurement platform 38 is rotated by means of the rotary stage 33 so that the upstream roller post 6, inclined post 7 and drum unit 5 can be measured. Since on the light receiving side the portions where the laser beam 14 is intercepted by the measurement object 70 become dark, and other portions with no interception become bright, light boundaries (a) through (1) are generated in the X-axis direction. Of these light boundaries (a) through (1), (f) and (g) indicate the boundaries for the roller post 6, while (h) and (i) indicate the boundaries for the inclined post 7. Since the tape 73 transmits the laser beam 14 therethrough, no boundary between brightness and darkness will appear due to the tape on the light receiving side.

More specifically, the upstream roller post 6 and inclined post 7 are irradiated with the laser beam 14 at the reference height (Z=0) shown in Fig. 8. With respect to the inclined post 7, the first X-projected position coordinates (S0, T0), which are the light boundaries (h) and (i) in the X-axis direction as explained above, are determined with the computation device 49 from both tangent points P0 and Q0 of the cross-sectional circle D0, which is generated when the inclined post 7 is cut with the laser beam 14. Next, in Fig. 9 wherein the measurement platform 38 is rotated by an angle of (γ) by means of the rotary stage 33 from the state of Fig. 8, the laser beam 14 is irradiated on the inclined post 7 and roller post 6. Then, from both tangent points PP0 and QQ0 of the cross-sectional circle DD0, which is generated when the inclined post 7 is cut with the laser beam 14, the second X-projected position coordinates (SS0, TT0) are found with the computation device 49. Then, from the first X-projected position coordinates (S0, T0) and the second X-projected position coordinates (SS0, TT0), the X-projected position coordinates (U0, UU0) of the center of the inclined post 7 as seen from the two directions, respectively, can be determined in approximation with the computation processing device 50. Similarly, the X-projected position coordinates (W0, WW0) of the center of the roller post 6 as seen from the two directions, respectively, can be determined. Hence in Fig. 6, the center distance (L) at the reference height (Z=0) between the upstream inclined post 7 and roller post 6 can be determined from the distance in the X direction (Lx), the distance in the Y direction (Ly) and the difference in rotational angle (γ) with the use of the Formula 1 mentioned before.

Similarly, the center distance (L) between the roller post 6 and drum unit 5 or between the tension post 61 and drum unit 5 can be determined. Also, the drum unit 5, downstream inclined post 8, and roller post 9 can be measured by rotating them until profile lines thereof are detected by the light receiving optical system.

As described above, all center distances (Ls) at an arbitrary height between the upstream roller post 6, inclined post 7, drum unit 5, downstream inclined post 8, roller post 9 and tension post 61 can be measured in a condition in which no contact is made and in which a force is added from the tape 73 that is provided with a constant tension.

As shown in Fig. 10, a tape drive 65 may be mounted on the chassis 12 to drive the tape 73 in the direction of the arrow B. The tape drive 65 comprises a post 66 and a pinch roller 67. By the tape 73 running in the direction of the arrow B while making contact with the measurement object 70, the tape tension will become higher towards the downstream side in the direction of movement of the tape 73, and the force applied to the measurement object 70 will also increase. In this case, the measurement object 70 comprises the principal components 1 through 9 of the VTR mechanism, tension device 60, and tape drive 65.

The two-dimensional position coordinate measurement device of the above-described construction operates as follows.

The tape 73 is first wound around the measurement object 70, and a constant tension is then applied thereto by means of the tension device 60. The tape 73 is run in the direction of the arrow B by means of the tape drive 65. Since the tape 73 transmits the laser beam 14 therethrough, no boundaries for brightness and darkness due to the tape will appear on the light receiving side. Since the measurement method is the same as that explained with reference to Fig. 7, its explanation will be omitted.

As described above, according to this preferred embodiment, it is possible to measure without contact all of the center distances (Ls) at an arbitrary height between the upstream roller post 6, inclined post 7, and drum unit 5, and between the downstream inclined post 8, roller post 9, and tension post 61. Moreover, measurement is possible in a condition in which the position-dependent force is exerted upon the measurement object 70 by the tape 73 which is running, i.e., in a condition unlimitedly close to the actual mode of recording or playback.

Although in the above-described embodiment the rotary stage 33 rotates the measurement object 70 about the Z axis, it may rotate the light emitting and receiving optical systems together, with the measurement

object 70 maintained stationary.

Fig. 11 depicts a position coordinate measurement device according to a second embodiment of the present invention. Note that elements that have already been explained will have identical reference numerals, and their description will be omitted.

In Fig. 11, the measurement object 70 is installed between a first light emitting optical system 151 and a first light receiving optical system 211, and between a second light emitting optical system 152 and a second light receiving optical system 212. The first optical system 151 and 211 is located at a position rotated by an angle of (γ) from the second optical system 152 and 212. Laser beams are emitted alternatively from the light emitting optical systems 151 and 152. The computation processing device 50 of Fig. 2 computes the center distance (L) of the measurement object 70 shown in Fig. 6, based on the angular difference (γ) in installation position of the first and second optical systems, instead of using the rotational angle (γ) detected by the rotational angle detection device 34, and the X-projected position coordinates (x1, x2, x3, ...) determined respectively by the first and second optical systems.

With respect to the two-dimensional position coordinate measurement device configured as above, its measurement method will be explained.

First, the first X-projected position coordinates are determined by irradiating on the measurement object 70 a laser beam from the first light emitting optical system 151. Next, the second X-projected position coordinates are determined by irradiating a laser beam from the second light emitting optical system 152. As for the method of finding the two-dimensional position coordinates, its explanation will be omitted, since it is the same as the one explained for the first embodiment.

Also, according to the second embodiment, it is possible to measure without contact the center distances (Ls) between all posts at an arbitrary height.

Note that in the second embodiment, an explanation was given as to the method of and device for finding the two-dimensional position coordinates from two sets of different X-projected position coordinates obtained by setting two units of optical systems, but since the two-dimensional position coordinates can be determined if at least two sets of different X-projected position coordinates are obtained, it is also possible to measure with three or more units installed. In that case, the measurement accuracy will improve further.

Fig. 12 depicts a three-dimensional position coordinate measurement device according to a third embodiment of the present invention.

As shown in Fig. 12, the light emitting and receiving optical systems 15 and 21 are mounted on respective Z-axis stages 30 and 31 for vertical movement thereof. The Z-axis stages 30 and 31 move the light emitting and receiving optical systems 15 and 21, respectively, always by the same length in the Z-axis direction generally perpendicular to the installation plane 39. The length (H) of vertical movement of the light emitting and receiving optical systems 15 and 21 is detected by means of a Z-axis scale 32 mounted on, for example, the Z-axis stage 30.

As shown in Fig. 13, the computation processing device 50 computes the inclination angle (ϕ_7), inclination direction (θ_7) and center distance (L') at an arbitrary height as shown in Fig. 17, based on the length (H) of vertical movement, rotational angle (γ), and X-projected position coordinates (x1, x2, x3, ...).

The position coordinate measurement device of Fig. 12 has two reference posts 68 and 69 as shown in Fig. 18 for the purpose of setting the light emitting and receiving optical systems 15 and 21 at the reference height (Z=0) of the mechanism. The center distance (E) at the reference height (Z=0) between the two reference posts 68 and 69 is already known. Here, the reference post 68 is set generally vertically against the installation plane 39, while the reference post 69 is slightly inclined. The two reference posts 68 and 69 have a diameter larger than that of the inclined posts 7 and 8 and that of the roller posts 6 and 9, and are spaced a larger distance from each other than the distance between the roller post 6 and inclined post 7 and that between the roller post 9 and inclined post 8. Therefore, measurements can be made adequately even with the conventional, contact-type position coordinate measurement device. The measurement object 70 in this preferred embodiment comprises the principal components 1 through 9 of the VTR mechanism and the reference posts 68 and 69.

The three-dimensional position coordinate measurement device configured as described above is discussed hereinafter, taking a measurement method for the upstream roller post 6, inclined post 7 and drum unit 5 as example.

As shown in Fig. 14, the measurement platform 38 is rotated by the rotary stage 33 for the measurement of the upstream roller post 6, inclined post 7 and drum unit 5. Since on the light receiving side the portions where the laser beam 14 is intercepted by the measurement object 70 become dark, and other portions not intercepted become bright, light boundaries (a) through (l) are generated in this order in the X-axis direction. Of these light boundaries (a) through (l), (b) and (c) indicate the boundaries for the roller post 6, while (d) and (e) indicate the boundaries for the inclined post 7.

More specifically, the laser beam 14 is irradiated at the height of (Z1) on the upstream roller post 6 and inclined post 7 as shown in Fig. 15. As for the inclined post 7, the first X-projected position coordinates (S1, T1), which are the light boundaries (d) and (e) in the X-axis direction as explained above, are determined from both tangent points P1 and Q1 of the cross-sectional circle D1 that is generated when the inclined post 7 is cut by the laser beam 14. Furthermore, the X-projected position coordinates (S1~S3, T1~T3) of the first profile line are determined with the computation device 49 by mov-

ing the Z-axis stages 30 and 31 simultaneously in the Z direction to (Z1)~(Z3), sequentially. Next, in Fig. 16 in which the measurement platform 38 has been rotated by an angle of (γ) by means of the rotary stage 33 from the condition of Fig. 15, the laser beam 14 is irradiated on the inclined post 7 and roller post 6 from a direction that differs by the angle of (γ). Then, while moving the Z-axis stages 30 and 31 simultaneously downward in the Z-axis direction to (Z3)~(Z1) in sequence, the X-projected position coordinates (SS3~SS1, TT3~TT1) of the second profile line of the inclined post 7 are determined with the computation device 49 by irradiating the laser beam 14. Finally, from the X-projected position coordinates (S1~S3, T1~T3) of the first profile line and the X-projected position coordinates (SS1~SS3, TT1~TT3) of the second profile line, the X-projected position coordinates {U(U1-U3), UU(UU1-UU3)} of the center lines of the inclined post 7 as seen from the two directions, respectively, can be determined in approximation with the computation processing device 50. Hence in Fig. 17, the inclination angle (ϕ_7) and inclination direction (θ_7) of the upstream inclined post 7 can be determined using Formula 2 given by:

$$\phi_7 = \tan^{-1}\frac{Z3\text{-}Z1}{G7},\quad \theta_7 = \sin^{-1}\frac{U3\text{-}U1}{G7}$$

where

$$G7 = \sqrt{\left\{\frac{(UU3\text{-}UU1)\text{-}(U3\text{-}U1)\cos\gamma}{\sin\gamma}\right\}^2 + (U3\text{-}U1)^2}$$

Similarly, the inclination angle (ϕ) and inclination direction (θ) of the roller post 6 and drum unit 5 can also be determined at the same time. The center distance (L') between the roller post 6 and inclined post 7 at the height (Z1) can be determined using Formula 3 given by:

$$L' = \sqrt{Lx^2 + Ly^2}$$

where Lx=U1-W1 and Ly={(U1-W1)-(UU1-WW1)/cosγ} /tanγ.

Furthermore, the center distance (Lα) at an arbitrary height (α) can be determined using Formula 4 given by:

$$L\alpha = \sqrt{(x_6\text{-}x_7)^2 + (y_6\text{-}y_7)^2}$$

where

$$x_6 = \text{-}(W3\text{-}W1)\,\frac{\alpha\text{-}Z1}{Z3\text{-}Z1}$$

$$y_6 = G7\cos\theta_6\,\frac{\alpha\text{-}Z1}{Z3\text{-}Z1}$$

$$x_7 = \text{-}(U3\text{-}U1)\,\frac{\alpha\text{-}Z1}{Z3\text{-}Z1} + Lx$$

$$y_7 = G7\cos\theta_7\,\frac{\alpha\text{-}Z1}{Z3\text{-}Z1} + Ly$$

Next, in order to find the center distance (L) at the reference height (Z=0) which is the center of the design, the difference (Z') between the reference height (Z=0) and (Z1) is determined from the reference posts 68 and 69 that are measured at the same time as the roller post 6, inclined post 7 and drum unit 5. As mentioned previously, the center distance (E) between the two reference posts 68 and 69 at the reference height (Z=0) is known. Also, the center distance at (Z1) is (E') from the measurement with the laser beam 14. In other words, since the inclination angle (ϕ) and inclination direction (θ) of the reference posts 68 and 69 have already been calculated by the computation processing device 50, it is possible to find the difference (Z') between the height, at which the center distance becomes (E), and (Z1). Accordingly, by substituting the value of height (α=Z1+Z') in Formula 4, the computation processing device 50 can determine the center distance (L) at the reference height (Z=0) between the roller post 6 and inclined post 7. Also, the drum unit 5, downstream inclined post 8 and roller post 9 can be measured by rotating the measurement object until a profile line is detected.

As indicated above, according to this preferred embodiment, it is possible to measure three-dimensionally and without contact all of the inclination angles (ϕs) and inclination directions (θs) and center distances (Ls) at the reference height (Z=0), which is the center of the design, between the upstream roller post 6, inclined post 7, drum unit 5, downstream inclined post 8, and roller post 9.

Note that in this preferred embodiment, a description was given for the method of and device for finding the three-dimensional position coordinates from two sets of different projected position coordinates obtained by rotating the measurement object, but measurement can be made similarly by rotating the light emitting and receiving optical systems relative to the measurement object. Furthermore, although in this preferred embodiment description was given for the case in which the laser beam is irradiated from two different directions, it is also possible to measure from three or more directions since the three-dimensional position coordinates can be determined if at least two sets of different X-projected position coordinates can be obtained. In that event, the measurement accuracy will improve further.

As best shown in Fig. 19, a tension device 60 may be mounted on the chassis 12 to provide a tape 73 with a constant tension. The tension device 60 comprises a tension post 61 which makes contact with the tape 73, a base 62 for retaining the tension post 61, and a spring 63 having one end connected to the chassis 12 and the other end connected to the base 62. Thus, the meas-

urement object 70 shown in Fig. 19 comprises the principal components 1 through 9 of the VTR mechanism, the tension device 60, and reference posts 68 and 69.

As described previously, the tape 73, wound around the measurement object 70 with a fixed angle, is a transparent tape such as, for example, a base film on which no magnetic substance is coated so that it transmits the laser beam 14 therethrough and has approximately the equivalent properties in terms of thickness and stiffness, with those of the magnetic tape for use in recording signals.

The three-dimensional position coordinate measurement device configured as described above is discussed hereinafter, taking a measurement method for the upstream roller post 6, inclined post 7 and drum unit 5 as example.

The tape 73 is first wound around individual components of the measurement object 70, and a constant tension is applied thereto by means of the tension device 60. Next, the measurement platform 38 is rotated by means of the rotary stage 33 so that the upstream roller post 6, inclined post 7 and drum unit 5 can be measured. Since on the light receiving side the portions where the laser beam 14 is intercepted by the measurement object 70 become dark, and other portions with no interception become bright, light boundaries (a) through (p) are generated in this order in the X-axis direction. Of these light boundaries (a) through (p), (f) and (g) indicate the boundaries for the roller post 6, while (h) and (i) indicate the boundaries for the inclined post 7. Since the tape 73 transmits the laser beam 14 therethrough, no boundary between brightness and darkness will appear due to the tape on the light receiving side.

More specifically, the laser beam 14 is irradiated at the height of (Z1) on the upstream roller post 6 and inclined post 7, as shown in Fig. 20. With respect to the roller post 6, the first X-projected position coordinates (S1, T1), which are the light boundaries (h) and (i) in the X-axis direction as explained above, are determined from both tangent points P1 and Q1 of the cross-sectional circle D1 which is generated when the inclined post 7 is cut by the laser beam 14. Furthermore, the Z-axis stages 30 and 31 are moved simultaneously in the Z direction to (Z2)~(Z3) in sequence, and the X-projected position coordinates {(S2, S3), (T2, T3)} of the first profile line are determined with the computation device 49. Next, in Fig. 21 in which the measurement platform 38 has been rotated by an angle of (γ) by means of the rotary stage 33 from the condition shown in Fig. 20, the laser beam 14 is irradiated on the inclined post 7 and roller post 6. Then, by irradiating the laser beam 14 while moving the Z stages 30 and 31 simultaneously downward in the Z direction to (Z3)~(Z1) in sequence, the X-projected position coordinates ({SS3~SS1), (TT3~TT1)} of the second profile lines of the inclined post 7 are determined with the computation device 49. Finally, from the X-projected position coordinates {(S1~S3), (T1-T3)} of the first profile lines and the X-projected position coordinates {(SS1~SS3), (TT1-TT3)} of the second profile lines, the X-projected position coordinates {U(U1~U3), UU(UU1-UU3)} of the center line of the inclined post 7 as seen from the two directions, respectively, are determined in approximation by means of the computation processing device 50. Accordingly, in Fig. 16, the inclination angle (ϕ7) and inclination direction (θ7) can be determined using the Formula 2 indicated previously.

Similarly, the inclination angle (ϕ) and inclination direction (θ) of the roller post 6, drum unit 5, tension post 61, etc., can also be determined. Further, the center distance (L') at the height of (Z1) between the roller post 6 and inclined post 7 can be determined using the Formula 3 indicated previously.

Also, the center distance (Lα) between the posts at an arbitrary height (α) can be determined with the Formula 4 indicated previously.

Moreover, the center distance (L) at the reference height (Z=0), which is the center of the design, can be determined with a method similar to that discussed above. Also, the drum unit 5, downstream inclined post 8, and roller post 9 can be measured, if rotated until a profile line can be detected.

Therefore, it becomes possible to measure all of the inclination angles (ϕs), inclination directions (θs), and the center distance (L) at the reference height (Z=0), which is the center of the design, of the upstream roller post 6, inclined post 7, drum unit 5, downstream inclined post 8, roller post 9, and tension post 61 three-dimensionally without contact and in a condition in which a force is added from the tape 73 having a constant tension.

As shown in Fig. 22, if the tape drive 65 comprising the post 66 and pinch roller 67 is mounted on the chassis 12, the tape 73 is driven by the tape drive 65 in the direction of the arrow B. The tape 73 runs in the direction of the arrow B in contact with the measurement object 70, and the tape tension increases as the tape 73 moves towards the downstream side in the direction of motion, adding larger force as well to the measurement object 70. The measurement object 70 shown in Fig. 22 comprises the principal components 1 through 9 of the VTR mechanism, tension device 60, tape drive 65, and reference posts 68 and 69.

With respect to the three-dimensional measurement device as configured above, its measurement method will be described.

The tape 73 is wound around the measurement object 70 and is provided with a constant tension by means of the tension device 60. Also, the tape 73 is run in the direction of the arrow B by means of the tape drive 65. Since the tape 73 transmits the laser beam 14 therethrough, no brightness/darkness boundary due to the tape will appear on the light receiving side. Since the measurement method is the same as that explained above, its description will be omitted.

According to this preferred embodiment, it is possi-

ble to measure three-dimensionally and without contact the inclination angles (ϕs), inclination directions (θs) and the center distances (Ls) at the reference height (Z=0), which is the center of the design, of the upstream roller post 6, inclined post 7, drum unit 5, downstream inclined post 8, roller post 9, and tension post 61. Moreover, measurement is possible in a condition in which the position-dependent force is exerted upon the measurement object 70 by the tape 73 which is running, i.e., in a condition unlimitedly close to the actual mode of recording or playback.

Fig. 23 depicts a three-dimensional position coordinate measurement device according to a fourth embodiment of the present invention.

As shown in Fig. 23, the measurement object 70 is installed between a first light emitting optical system 151 and a first light receiving optical system 211. These optical systems 151 and 211 are mounted on respective Z-axis stages 301 and 311 for vertical movement thereof. The Z-axis stages 301 and 311 move the first light emitting and receiving optical systems 151 and 211, respectively, always by the same length in the Z-axis direction generally perpendicular to the installation plane 39. The length (H) of vertical movement of the first light emitting and receiving optical systems 151 and 211 is detected by means of a Z-axis scale 321 mounted on, for example, the Z-axis stage 301.

Moreover, a second optical system comprising a light emitting optical system 152 and a light receiving optical system 212 is installed at a position rotated by an angle of (γ) with respect to the first optical system. The second light emitting and receiving optical systems 152 and 212 are mounted on respective Z-axis stages 302 and 312 for vertical movement thereof. The Z-axis stages 302 and 312 move the second light emitting and receiving optical systems 152 and 212, respectively, always by the same length in the Z-axis direction generally perpendicular to the installation plane 39. The length (H) of vertical movement of the second light emitting and receiving optical systems 302 and 312 is detected by means of a Z-axis scale 322 mounted on, for example, the Z-axis stage 302.

The first and second light emitting optical systems 151 and 152 alternately emit respective laser beams.

As shown in Fig. 13, the computation processing device 50 computes the inclination angle (ϕ), inclination direction (θ) and center distance (L') at an arbitrary height as shown in Fig. 17, based on the angular difference (γ) in installation position of the first and second optical systems, instead of using the rotational angle (γ) detected by the rotational angle detection device 34, and the X-projected position coordinates (x1, x2, x3, ...) determined respectively by the first and second optical systems.

The measurement method by the three-dimensional position coordinate measurement device as configured above will be explained.

The first X-projected position coordinates are determined by emitting a laser beam on the measurement object 70 from the first light emitting optical system 151. Next, the second X-projected position coordinates are determined by emitting a laser beam from the second light emitting optical system 152. The remainder of the method of determining the three-dimensional position coordinates is the same as that explained above, so its description will be omitted.

According to this preferred embodiment, it is possible to measure three-dimensionally and without contact the inclination angles (ϕs), inclination directions (θs) and center distances (Ls) of all posts at the reference height (Z=0), which is the center of the design.

Although in the above-described embodiments the light emitting and receiving optical systems are moved vertically relative to the measurement object 70, the measurement object 70 may be moved vertically with the light emitting and receiving optical systems maintained stationary.

Although the number of posts is limited in the above-described embodiments, it is needless to say that other posts can also be measured in a similar manner. Moreover, since measurement can be made regardless of the amount of the inclination angle of the post, there will be no loss in measurement accuracy as the inclination angle increases, as was the case with the conventional contact-type position coordinate measurement systems. Furthermore, even with posts that are small in diameter and easily bend when a load is applied thereto, measurement can be made with good accuracy due to its non-contact nature.

Also, the measurement system of the present invention is smaller than the conventional contact-type position coordinate measurement systems, and hence it can be used for such application as inspection of assembly accuracy, which is generally performed in an assembly adjustment line of the VTR mechanisms.

Furthermore, in the above-described embodiments, a description has been given for the case of VTR mechanism's components being the measurement object, objects other than the foregoing can be measured as well.

Also, although two reference posts are used to set the reference height, other methods such as measuring a magnetic head may be used to establish its height.

Claims

1. A method for determining the relative positions of a plurality of objects comprising the steps of:

   (a) placing the plurality of objects (5,6,7,8,9,10) to be measured on a plane (39);
   (b) irradiating a laser beam on said plurality of objects (5,6,7,8,9,10) from a plurality of different directions while said laser beam is being moved in a direction generally perpendicular to

said plane (39), said laser beam having a predetermined diameter and scanning parallel to said plane (39);

(c) computing a plurality of different projected position coordinates of said plurality of objects (5,6,7,8,9,10) from two tangent points of a cross-section which is generated when said plurality of objects (5,6,7,8,9,10) are cut with said laser beam; and

(d) computing three-dimensional position coordinates of said plurality of objects (5,6,7,8,9,10) and distances between said plurality of objects, from said different projected coordinates, the angular difference between said different directions, and the length of movement of said laser beam.

2. A method according to claim 1, in which the distance, L, between a first object of the plurality of objects, and a second object of the plurality of objects is determined by the equation:

$$L=\sqrt{(U0-W0)^2+\left(\frac{(U0-W0)-\frac{(UU0-WW0)}{\cos\gamma}}{\tan\gamma}\right)^2}$$

in which:

U0 is the position of the first object in the direction of scanning of the laser beam in a first direction;
W0 is the position of the second object in the direction of scanning of the laser beam in the first direction;
UU0 is the position of the first object in the direction of scanning of the laser beam in a second direction;
WW0 is the position of the second object in the direction of scanning of the laser beam in the second direction; and,
γ is the angle between the first and the second direction.

3. A method according to claim 1 or 2, in which the angle of inclination, ϕ, of one of said plurality of objects is determined by the equation:

$$\phi = \tan^{-1}\left(\frac{Z3-Z1}{G}\right)$$

where

$$G=\sqrt{\left(\frac{(UU3-UU1)-(U3-U1)\cos\gamma}{\sin\gamma}\right)^2+(U3-U1)^2}$$

Z1 is the first height;
Z3 is the second height;
U1 is the position of the object in the direction of scanning of the laser beam in a first position at the first height Z1;
U3 is the position of the object in the direction of scanning of the laser beam in the first position at the second height Z3;
UU1 is the position of the object in the direction of scanning of the laser beam in a second position at the first height Z1;
UU3 is the position of the object in the direction of scanning of the laser beam in the second position at the second height Z3; and,
γ is the angle between the first and second position.

4. A method according to claim 3, in which the inclination direction, θ, is determined by the equation:

$$\theta = \sin^{-1}\left(\frac{U3-U1}{G}\right).$$

5. A device for determining the relative positions of a plurality of objects, the device comprising:

a plane (39) on which a plurality of objects (5,6,7,8,9,10) to be measured is placed;
a light emitting optical system (15) for emitting a laser beam having a predetermined diameter and scanning parallel to said plane (39);
a light receiving optical system (21) having a photodetector (23) for detecting said laser beam;
a drive means for moving one of said plurality of objects (5,6,7,8,9,10) and said light emitting and receiving optical systems (15,21) relative to each other so that said plurality of objects (5,6,7,8,9,10) are irradiated with a laser beam at a plurality of heights;
a movement detection means (32) for detecting the length of movement of said one of said plurality of objects (5,6,7,8,9,10) and said light emitting and receiving optical systems (15,21)
a rotating means (33) for rotating one of said plurality of objects (5,6,7,8,9,10) and said light emitting and receiving optical systems (15,21) relative to each other to thereby change an angle by which said plurality of objects (5,6,7,8,9,10) are irradiated;
a rotational angle detection means (34) for detecting the angle of rotation of said one of said plurality of objects (5,6,7,8,9,10) and said light emitting and receiving optical systems (15,21);
a computation means for determining a plurality of different projected coordinates of said plurality of objects (5,6,7,8,9,10) from outputs of said

photodetector (23) by irradiating the objects (5,6,7,8,9,10) from a plurality of different directions; and

a computation processing means for determining three-dimensional position coordinates of said plurality of objects (5,6,7,8,9,10) and distances between said plurality of objects (5,6,7,8,9,10) from said different projection position coordinates of said plurality of objects, said angle of rotation, and said length of movement.

6. A device according to claim 5, further comprising a tape (73) which is brought into contact with said plurality of objects (5,6,7,8,9,10) and allows said laser beam to transmit therethrough, and a tension means for applying a tension to said tape (73), wherein said computation processing means determines the three-dimensional position coordinates of said plurality of objects (5,6,7,8,9,10), and said distances between said plurality of objects (5,6,7,8,9,10), with which said tape (73) having said tension is in contact.

7. A device according to claim 6, further comprising a tape drive means for moving said tape (73) relative to said plurality of objects (5,6,7,8,9,10), wherein said computation processing means determines the three-dimensional position coordinates of said plurality of objects with said tape (73) in motion.

8. A device according to any one of claims 5 to 7, in which the computation processing means is arranged to determine the distance, L, between a first object of the plurality of objects, and a second object of the plurality of objects by the equation:

$$L=\sqrt{(U0-W0)^2+\left(\frac{(U0-W0)-\frac{(UU0-WW0)}{\cos\gamma}}{\tan\gamma}\right)^2}$$

in which:

U0 is the position of the first object in the direction of scanning of the laser beam in a first direction;
W0 is the position of the second object in the direction of scanning of the laser beam in the first direction;
UU0 is the position of the first object in the direction of scanning of the laser beam in a second direction;
WW0 is the position of the second object in the direction of scanning of the laser beam in the second direction; and,
γ is the angle between the first and the second direction.

9. A device according to any one of claims 5 to 8, in which the computation processing means is arranged to determine the angle of inclination, ϕ, of one of said plurality of objects by the equation:

$$\phi=\tan^{-1}\left(\frac{Z3-Z1}{G}\right)$$

where

$$G=\sqrt{\left(\frac{(UU3-UU1)-(U3-U1)\cos\gamma}{\sin\gamma}\right)^2+(U3-U1)^2}$$

Z1 is the first height;
Z3 is the second height;
U1 is the position of the object in the direction of scanning of the laser beam in a first position at the first height Z1;
U3 is the position of the object in the direction of scanning of the laser beam in the first position at the second height Z3;
UU1 is the position of the object in the direction of scanning of the laser beam in a second position at the first height Z1;
UU3 is the position of the object in the direction of scanning of the laser beam in the second position at the second height Z3; and,
γ is the angle between the first and second position.

10. A device according to claim 9, in which the computation processing means is arranged to determine the inclination direction, θ, by the equation:

$$\theta=\sin^{-1}\left(\frac{U3-U1}{G}\right).$$

Patentansprüche

1. Verfahren zum Bestimmen der relativen Positionen einer Vielzahl von Objekten, mit den Schritten:

(a) die zu messende Vielzahl von Objekten (5, 6, 7, 8, 9, 10) wird auf einer Ebene (39) angeordnet;

(b) ein Laserstrahl wird auf die Vielzahl von Objekten (5, 6, 7, 8, 9, 10) aus einer Vielzahl von verschiedenen Richtungen gestrahlt, während der Laserstrahl in einer im allgemeinen zu der Ebene (39) senkrechten Richtung bewegt wird, wobei der Laserstrahl einen vorbestimmten

Durchmesser aufweist und die Ebene (39) parallel überstreicht;

(c) eine Vielzahl von verschiedenen, geplanten Positionskoordinaten der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) werden aus zwei Tangentenpunkten eines Querschnittes, welcher erzeugt wird, wenn die Vielzahl von Objekten (5, 6, 7, 8, 9, 10) mit dem Laserstrahl geschnitten wird, berechnet; und

(d) dreidimensionale Positionskoordinaten der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) und Abstände zwischen der Vielzahl von Objekten werden aus den verschiedenen, geplanten Koordinaten, der Winkeldifferenz zwischen den verschiedenen Richtungen und der Länge der Bewegung des Laserstrahls berechnet.

2. Verfahren nach Anspruch 1, in welchem der Abstand L zwischen einem ersten Objekt der Vielzahl von Objekten und einem zweiten Objekt der Vielzahl von Objekten durch die Gleichung:

$$L = \sqrt{(U0\text{-}W0)^2 + \left(\frac{(U0\text{-}W0)\text{-}\frac{(UU0\text{-}WW0)}{\cos\gamma}}{\tan\gamma}\right)^2}$$

bestimmt wird, in welcher:

U0 die Position des ersten Objektes in der Überstreichrichtung des Laserstrahls in einer ersten Richtung ist;

W0 die Position des zweiten Objektes in der Überstreichrichtung des Laserstrahls in der ersten Richtung ist;

UU0 die Position des ersten Objektes in der Überstreichrichtung des Laserstrahls in einer zweiten Richtung ist;

WW0 die Position des zweiten Objektes in der Überstreichrichtung des Laserstrahls in der zweiten Richtung ist; und

γ der Winkel zwischen der ersten und der zweiten Richtung ist.

3. Verfahren nach Anspruch 1 oder 2, in welcher der Neigungswinkel ϕ eines aus der Vielzahl von Objekten durch die Gleichung:

$$\Phi = \tan^{-1}\left(\frac{Z3\text{-}Z1}{G}\right)$$

bestimmt wird, wobei

$$G = \sqrt{\left(\frac{(UU3\text{-}UU1) - (U3\text{-}U1)\cos\gamma}{\sin\gamma}\right)^2 + (U3\text{-}U1)^2}$$

ist;

Z1 die erste Höhe ist;

Z3 die zweite Höhe ist;

U1 die Position des Objektes in der Uberstreichrichtung des Laserstrahls in einer ersten Position in der ersten Höhe Z1 ist;

U3 die Position des Objektes in der Überstreichrichtung des Laserstrahls in der ersten Postion in der zweiten Höhe Z3 ist;

UU1 die Position des Objektes in der Uberstreichrichtung des Laserstrahls in einer zweiten Position in der ersten Höhe Z1 ist;

UU3 die Position des Objektes in der Überstreichrichtung des Laserstrahls in der zweiten Position in der zweiten Höhe Z3 ist; und

γ der Winkel zwischen der ersten und der zweiten Position ist.

4. Verfahren nach Anspruch 3, in welchem die Neigungsrichtung Θ durch die Gleichung:

$$\Theta = \sin^{-1}\left(\frac{U3\text{-}U1}{G}\right)$$

bestimmt wird.

5. Vorrichtung zum Bestimmen der relativen Positionen einer Vielzahl von Objekten, wobei die Vorrichtung aufweist:

eine Ebene (39), auf welcher eine Vielzahl von zu messenden Objekten (5, 6, 7, 8, 9, 10) angeordnet ist;

ein lichtaussendendes, optisches System (15) zum Aussenden eines Laserstrahls mit einem vorbestimmten Durchmesser und zum parallelen Überstreichen der Ebene (39);

ein lichtempfangendes, optisches System (21) mit einem Fotodetektor (23) zum Detektieren des Laserstrahls;

ein Antriebsmittel zum Bewegen eines aus der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) und der lichtaussendenden und -empfangenden, optischen Systeme (15, 21) relativ zueinander, so daß die Vielzahl von Objekten (5, 6, 7, 8, 9, 10) mit einem Laserstrahl in einer Vielzahl von Höhen bestrahlt wird;

ein Bewegungserfassungsmittel (32) zum Erfassen der Länge der Bewegung von dem einen aus der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) und der lichtaussendenden und -empfangenden, optischen Systeme (15, 21);

ein Rotationsmittel (33) zum Rotieren eines aus der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) und der lichtaussendenden und -empfangenden, optischen Systeme (15, 21) relativ zueinander, um somit einen Winkel zu verändern, mit welchem die Vielzahl von Objekten (5, 6, 7, 8, 9, 10) bestrahlt wird;

ein Rotationswinkelerfassungsmittel (34) zum Erfassen des Rotationswinkels des einen aus der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) und der lichtaussendenden und -empfangenden, optischen Systeme (15, 21);

ein Berechnungsmittel zum Bestimmen einer Vielzahl von verschiedenen, geplanten Koordinaten der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) aus den Ausgängen des Fotodetektors (23) durch Bestrahlen der Objekte (5, 6, 7, 8, 9, 10) aus einer Vielzahl von verschiedenen Richtungen; und

ein Berechnungsverarbeitungsmittel zum Bestimmen dreidimensionaler Positionskoordinaten der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) und von Abständen zwischen der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) aus den verschiedenen Projektionspositionskoordinaten der Vielzahl von Objekten, dem Rotationswinkel und der Länge der Bewegung.

6. Vorrichtung nach Anspruch 5, weiterhin ein Band (73) aufweisend, welches in Kontakt mit der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) gebracht wird, und es dem Laserstrahl erlaubt, durch dieses hindurchzutreten, und ein Spannungsmittel zum Anlegen einer Spannung an das Band (73), wobei die Berechnungsverarbeitungsmittel die dreidimensionalen Positionskoordinaten der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) und die Abstände zwischen der Vielzahl von Objekten (5, 6, 7, 8, 9, 10) bestimmen, mit denen das Band (73), welches die Spannung aufweist, in Kontakt ist.

7. Vorrichtung nach Anspruch 6, weiterhin enthaltend ein Bandantriebsmittel zum Bewegen des Bandes (73) relativ zu der Vielzahl von Objekten (5, 6, 7, 8, 9, 10), wobei die Berechnungsverarbeitungsmittel die dreidimensionalen Positionskoordinaten der Vielzahl von Objekten bestimmen, während das Band (73) in Bewegung ist.

8. Vorrichtung nach einem der Ansprüche 5 bis 7, in welcher die Berechungsverarbeitungsmittel ausgelegt sind, um den Abstand L zwischen einem ersten Objekt der Vielzahl von Objekten und einem zweiten Objekt der Vielzahl von Objekten durch die Gleichung:

$$L = \sqrt{(U0\text{-}W0)^2 + \left(\frac{(U0\text{-}W0)\text{-}\dfrac{(UU0\text{-}WW0)}{\cos\gamma}}{\tan\gamma}\right)^2}$$

zu bestimmen, in welcher:

U0 die Position des ersten Objektes in der Überstreichrichtung des Laserstrahls in einer ersten Richtung ist;

W0 die Position des zweiten Objektes in der Überstreichrichtung des Laserstrahls in der ersten Richtung ist;

UU0 die Postion des ersten Objektes in der Überstreichrichtung des Laserstrahls in einer zweiten Richtung ist;

WW0 die Position des zweiten Objektes in der Überstreichrichtung des Laserstrahls in der zweiten Richtung ist; und

γ der Winkel zwischen der ersten und der zweiten Richtung ist.

9. Vorrichtung nach einem der Ansprüche 5 bis 8, in welcher die Berechnungsverarbeitungsmittel ausgelegt sind, um den Neigungswinkel ϕ von einem aus der Vielzahl von Objekten durch die Gleichung:

$$\Phi = \tan^{-1}\left(\frac{Z3\text{-}Z1}{G}\right)$$

zu bestimmen, wobei

$$G = \sqrt{\left(\frac{(UU3\text{-}UU1) - (U3\text{-}U1)\cos\gamma}{\sin\gamma}\right)^2 + (U3\text{-}U1)^2}$$

ist;

Z1 die erste Höhe ist;

Z3 die zweite Höhe ist;

U1 die Position des Objektes in der Überstreichrichtung des Laserstrahls in einer ersten Position in der ersten Höhe Z1 ist;

U3 die Position des Objektes in der Überstreichrichtung des Laserstrahls in der ersten Position in der zweiten Höhe Z3 ist;

UU1 die Position des Objektes in der Überstreichrichtung des Laserstrahls in einer zweiten Position in der ersten Höhe Z1 ist;

UU3 die Position des Objektes in der Überstreichrichtung dees Laserstrahls in der zweiten Position in der zweiten Höhe Z3 ist; und

γ der Winkel zwischen der ersten und der zweiten Position ist.

10. Vorrichtung nach Anspruch 9, in welcher die Berechnungsverarbeitungsmittel auslegt sind, um die Neigungsrichtung Θ durch die Gleichung:

$$\Theta = \sin^{-1}\left(\frac{U3-U1}{G}\right)$$

zu bestimmen.

Revendications

1. Procédé pour déterminer les positions relatives de plusieurs objets, comprenant les étapes consistant à:

(a) placer les plusieurs objets (5,6,7,8,9,10) à mesurer sur un plan (39) :
(b) envoyer un faisceau laser sur lesdits plusieurs objets (5,6,7,8,9,10) à partir de plusieurs directions différentes pendant que ledit faisceau laser est déplacé dans une direction généralement perpendiculaire audit plan (39), ledit faisceau laser présentant un diamètre prédéterminé et effectuant un balayage parallèlement audit plan (39) ;
(c) calculer plusieurs coordonnées de positions en projection différentes desdits plusieurs objets (5,6,7,8,9,10) à partir de deux points tangents d'une section transversale qui est générée lorsque lesdits plusieurs objets (5,6,7,8,9,10) sont rencontrés par ledit faisceau laser; et
(d) calculer des coordonnées de positions en trois dimensions desdits plusieurs objets (5,6,7,8,9,10) et des distances entre lesdits plusieurs objets à partir desdites différentes coordonnées en projection, de la différence angulaire entre lesdites directions différentes et de la longueur du déplacement dudit faisceau laser.

2. Procédé selon la revendication 1, dans lequel la distance L entre un premier objet parmi les plusieurs objets, et un second objet parmi les plusieurs objets, est déterminée par l'équation:

$$L=\sqrt{(U0-W0)^2+\left(\frac{(U0-W0)-\frac{(UU0-WW0)}{\cos\gamma}}{\tan\gamma}\right)^2}$$

dans laquelle:

U0 est la position du premier objet dans la direction de balayage du faisceau laser dans une première direction;
W0 est la position du second objet dans la direction de balayage du faisceau laser dans la première direction;
UU0 est la position du premier objet dans la direction de balayage du faisceau laser dans une seconde direction;
WW0 est la position du second objet dans la direction de balayage du faisceau laser dans la seconde direction; et,
γ est l'angle entre la première et la seconde directions.

3. Procédé selon la revendication 1 ou 2, dans lequel l'angle d'inclinaison Φ de l'un desdits plusieurs objets est déterminé par l'équation:

$$\phi = \tan^{-1}\left(\frac{Z3-Z1}{G}\right)$$

où

$$G=\sqrt{\left\{\frac{(UU3-UU1)-(U3-U1)\cos\gamma}{\sin\gamma}\right\}^2+(U3-U1)^2}$$

Z1 est la première hauteur;
Z3 est la seconde hauteur;
U1 est la position de l'objet dans la direction de balayage du faisceau laser dans une première position à la première hauteur Z1;
U3 est la position de l'objet dans la direction de balayage du faisceau laser dans la première position à la seconde hauteur Z3;

UU1 est la position de l'objet dans la direction de balayage du faisceau laser dans une seconde position à la première hauteur Z1;
UU3 est la position de l'objet dans la direction de balayage du faisceau laser dans la seconde position à la seconde hauteur Z3; et,
γ est l'angle entre la première et la seconde positions.

4. Procédé selon la revendication 3, dans lequel la direction d'inclinaison θ est déterminée par l'équation:

$$\theta = \sin^{-1}\left(\frac{U3-U1}{G}\right).$$

5. Dispositif pour déterminer les positions relatives de plusieurs objets, le dispositif comprenant:

un plan (39) sur lequel sont placés les plusieurs objets (5,6,7,8,9,10) à mesurer;
un système optique (15) photoémetteur pour émettre un faisceau laser présentant un diamètre prédéterminé et assurant un balayage parallèlement audit plan (39);
un système optique (21) photorécepteur présentant un photodétecteur (23) pour détecter ledit faisceau laser;
un moyen d'entraînement pour déplacer l'un desdits plusieurs objets (5,6,7,8,9,10) et lesdits systèmes optiques (15,21) photoémetteur et photorécepteur l'un par rapport à l'autre de telle sorte que lesdits plusieurs objets (5,6,7,8,9,10) sont frappés par un faisceau laser à plusieurs hauteurs;
un moyen (32) de détection de mouvement pour détecter la longueur du déplacement dudit premier parmi lesdits plusieurs objets (5,6,7,8,9,10) et lesdits systèmes optiques (15,21) photoémetteur et photorécepteur;
un moyen de rotation (33) pour faire tourner l'un desdits plusieurs objets (5,6,7,8,9,10) et lesdits systèmes optiques (15,21) photoémetteur et photorécepteur l'un par rapport à l'autre pour ainsi changer un angle selon lequel lesdits plusieurs objets (5,6,7,8,9,10) sont irradiés;
un moyen (34) de détection d'un angle de rotation pour détecter l'angle de rotation dudit premier parmi lesdits plusieurs objets (5,6,7,8,9,10) et lesdits systèmes optiques (15,21) photoémetteur et photorécepteur;
un moyen de calcul pour déterminer plusieurs coordonnées différentes en projection desdits plusieurs objets (5,6,7,8,9,10) à partir des signaux produit par ledit photodétecteur (23) par l'irradiation des objets (5,6,7,8,9,10) à partir de plusieurs directions différentes;
un moyen de traitement de calcul pour déterminer des coordonnées de position en trois dimensions desdits plusieurs objets (5,6,7,8,9,10) et des distances entre lesdits plusieurs objets (5,6,7,8,9,10) à partir desdites coordonnées de position en projection différentes desdits plusieurs objets, dudit angle de rotation et de ladite longueur de déplacement.

6. Dispositif selon la revendication 5, comprenant de plus une bande (73) qui est amenée en contact avec lesdits plusieurs objets (5,6,7,8,9,10) et se laisse traverser par ledit faisceau laser, et un moyen de tension pour appliquer une tension sur ladite bande (73), dans lequel ledit moyen de traitement de calcul détermine les coordonnées de position en trois dimensions desdits plusieurs objets (5,6,7,8,9,10), et lesdites distances entre lesdits plusieurs objets (5,6,7,8,9,10) avec lesquels ladite bande (73) présentant ladite tension est en contact.

7. Dispositif selon la revendication 6, comprenant de plus un moyen d'entraînement de bande pour déplacer ladite bande (73) par rapport auxdits plusieurs objets (5,6,7,8,9,10), dans lequel ledit moyen de traitement de calcul détermine les coordonnées de position en trois dimensions desdits plusieurs objets avec ladite bande (73) en mouvement.

8. Dispositif selon l'une quelconque des revendications 5 à 7, dans lequel le moyen de traitement de calcul est agencé pour déterminer la distance L entre un premier objet parmi les plusieurs objets, et un second objet parmi les plusieurs objets par l'équation:

$$L=\sqrt{(U0-W0)^2+\left(\frac{(U0-W0)-\frac{(UU0-WW0)}{\cos\gamma}}{\tan\gamma}\right)^2}$$

dans laquelle:

U0 est la position du premier objet dans la direction de balayage du faisceau laser dans une première direction;
W0 est la position du second objet dans la direction de balayage du faisceau laser dans la première direction;
UU0 est la position du premier objet dans la direction de balayage du faisceau laser dans une seconde direction;
WW0 est la position du second objet dans la direction de balayage du faisceau laser dans la seconde direction; et,
γ est l'angle entre la première et la seconde directions.

9. Dispositif selon l'une quelconque des revendica-

tions 5 à 8, dans lequel le moyen de traitement de calcul est agencé pour déterminer l'angle d'inclinaison Φ de l'un desdits plusieurs objet par l'équation

$$\phi = \tan^{-1}\left(\frac{Z3-Z1}{G}\right)$$

où

$$G = \sqrt{\left\{\frac{(UU3-UU1) - (U3-U1)\cos\gamma}{\sin\gamma}\right\}^2 + (U3-U1)^2}$$

Z1 est la première hauteur;
Z3 est la seconde hauteur;
U1 est la position de l'objet dans la direction de balayage du faisceau laser dans une première position à la première hauteur Z1;
U3 est la position de l'objet dans la direction de balayage du faisceau laser dans la première position à la seconde hauteur Z3;
UU1 est la position de l'objet dans la direction de balayage du faisceau laser dans une seconde position à la première hauteur Z1;
UU3 est la position de l'objet dans la direction de balayage du faisceau laser dans la seconde position à la seconde hauteur Z3; et,
γ est l'angle entre la première et la seconde positions.

10. Dispositif selon la revendication 9, dans lequel le moyen de traitement de calcul est agencé pour déterminer la direction d'inclinaison θ par l'équation:

$$\theta = \sin^{-1}\left(\frac{U3-U1}{G}\right).$$

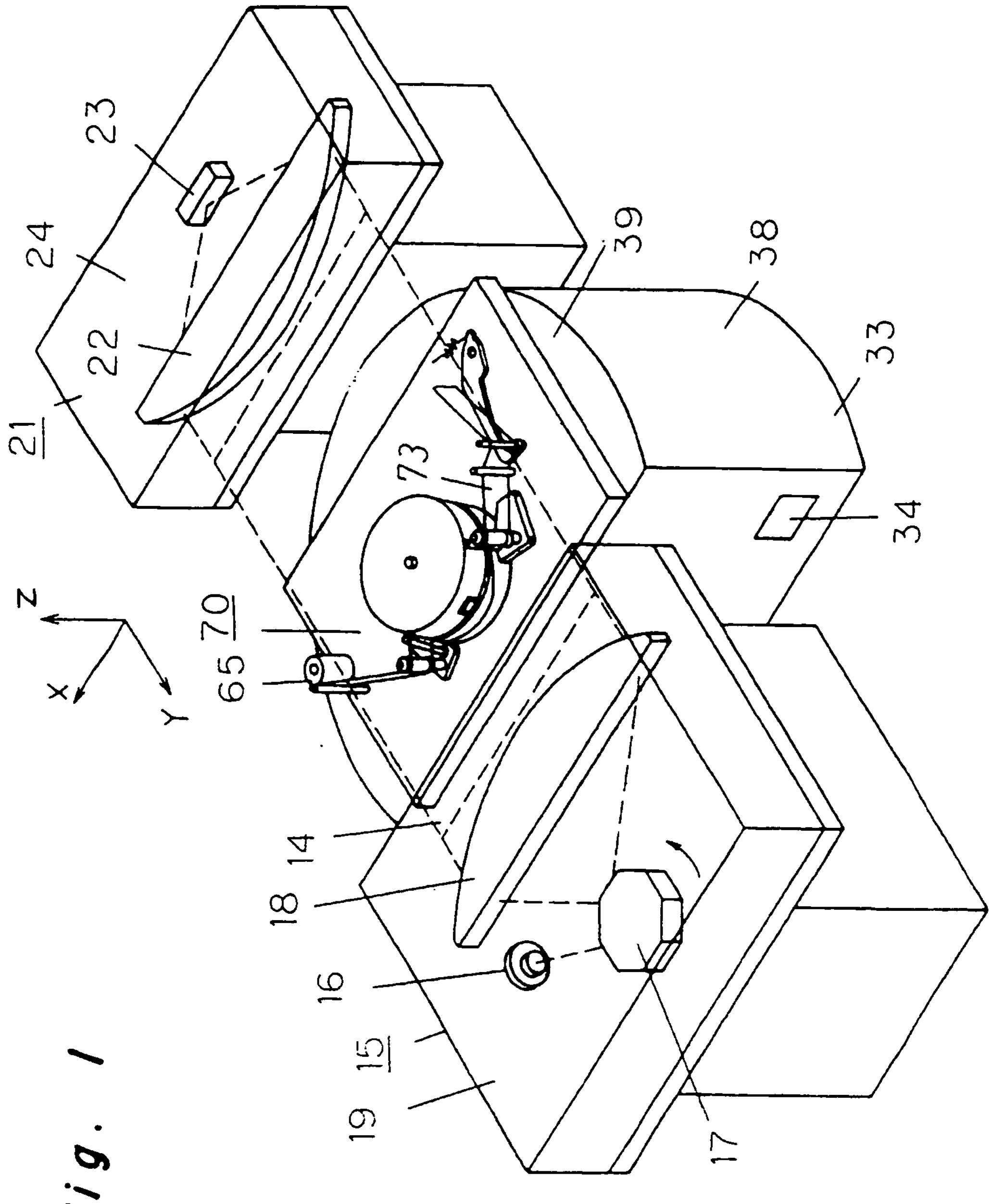
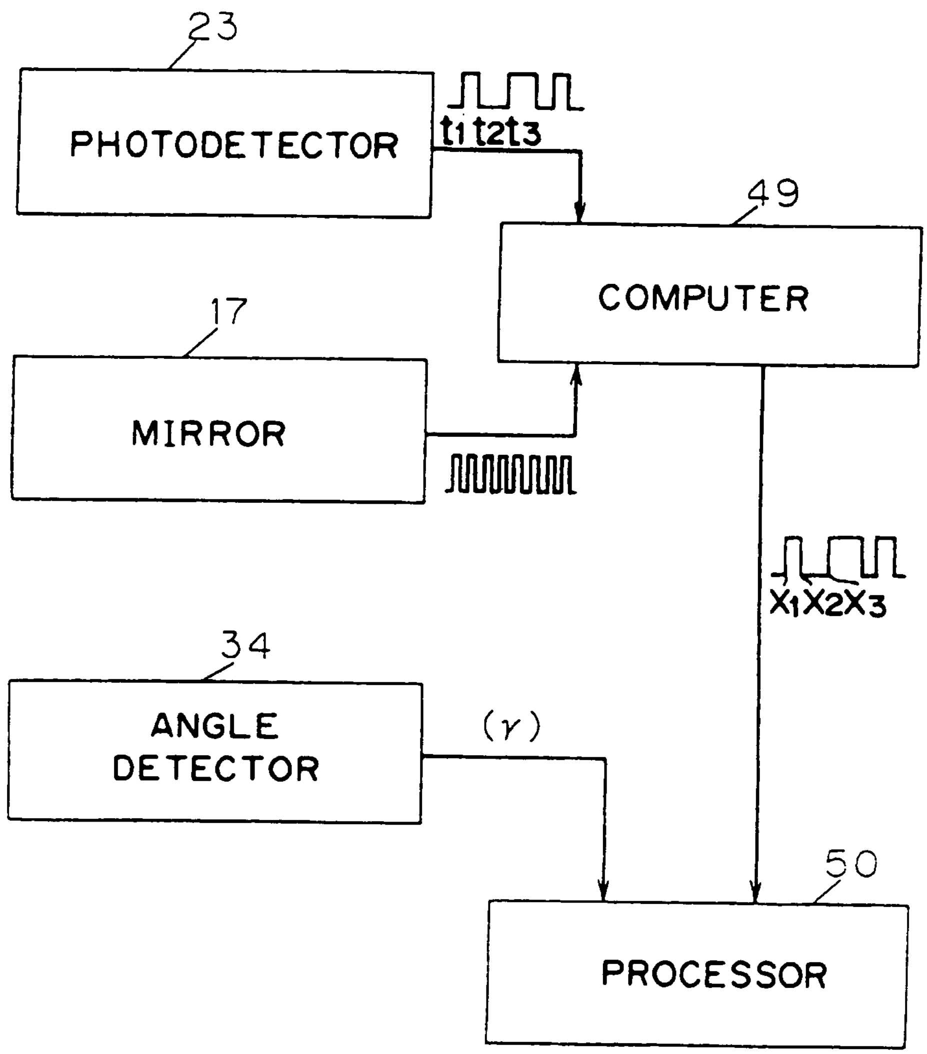


Fig. 1

Fig. 2


23
PHOTODETECTOR
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49
COMPUTER
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MIRROR
X1 X2 X3
34
ANGLE
DETECTOR
(γ)
50
PROCESSOR

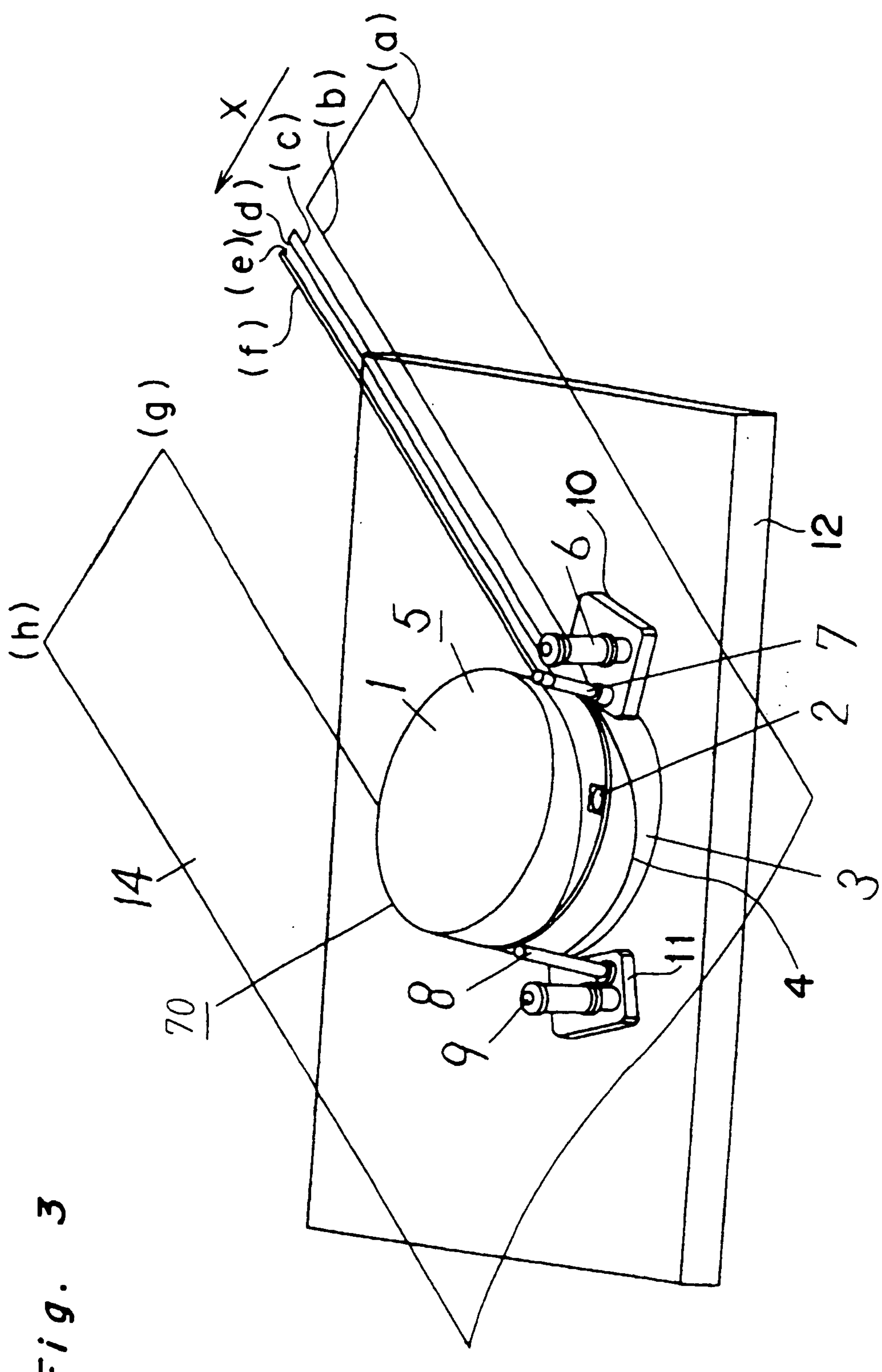

Fig. 3

Fig. 4

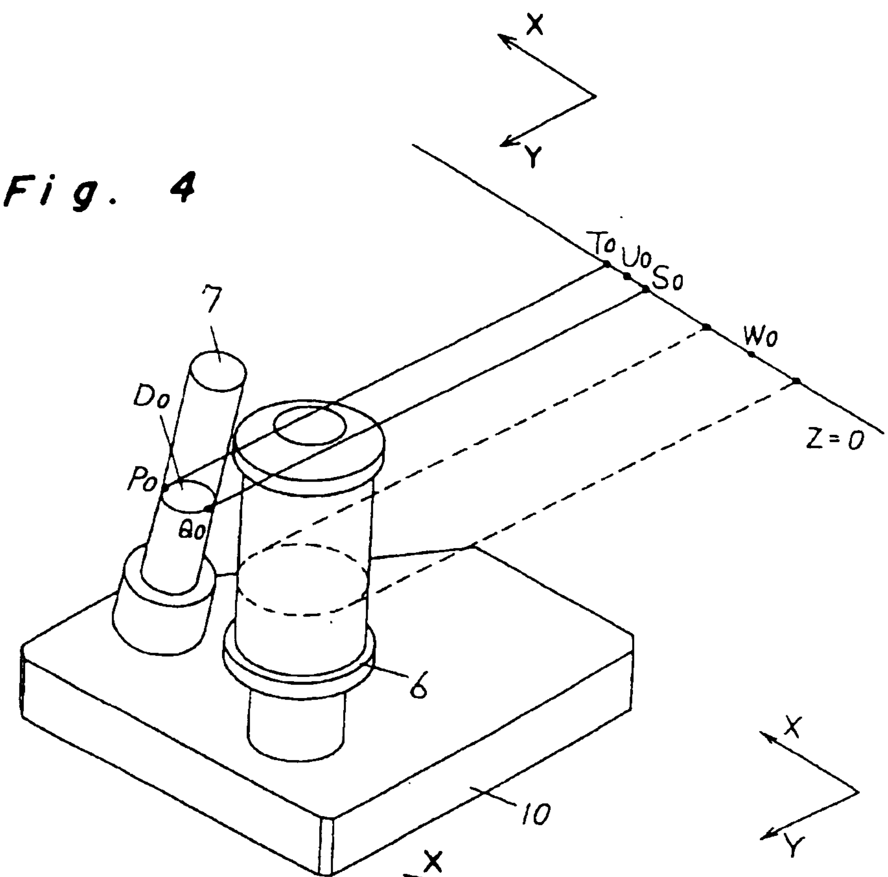
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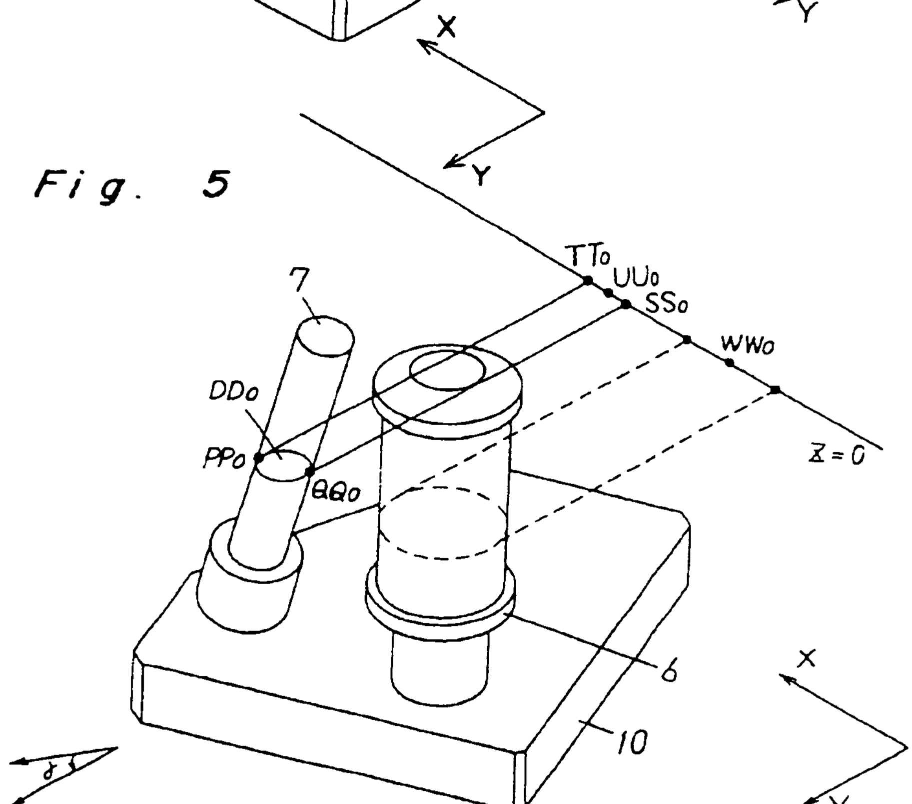
Fig. 5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DDo
PPo
QQo
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X
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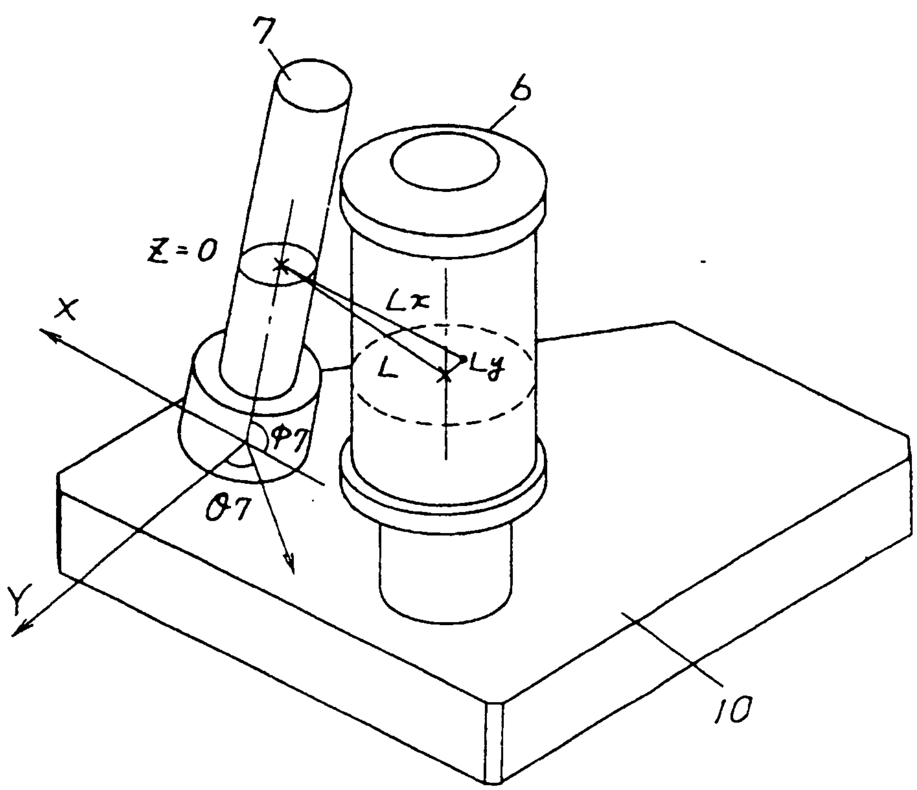
Fig. 6



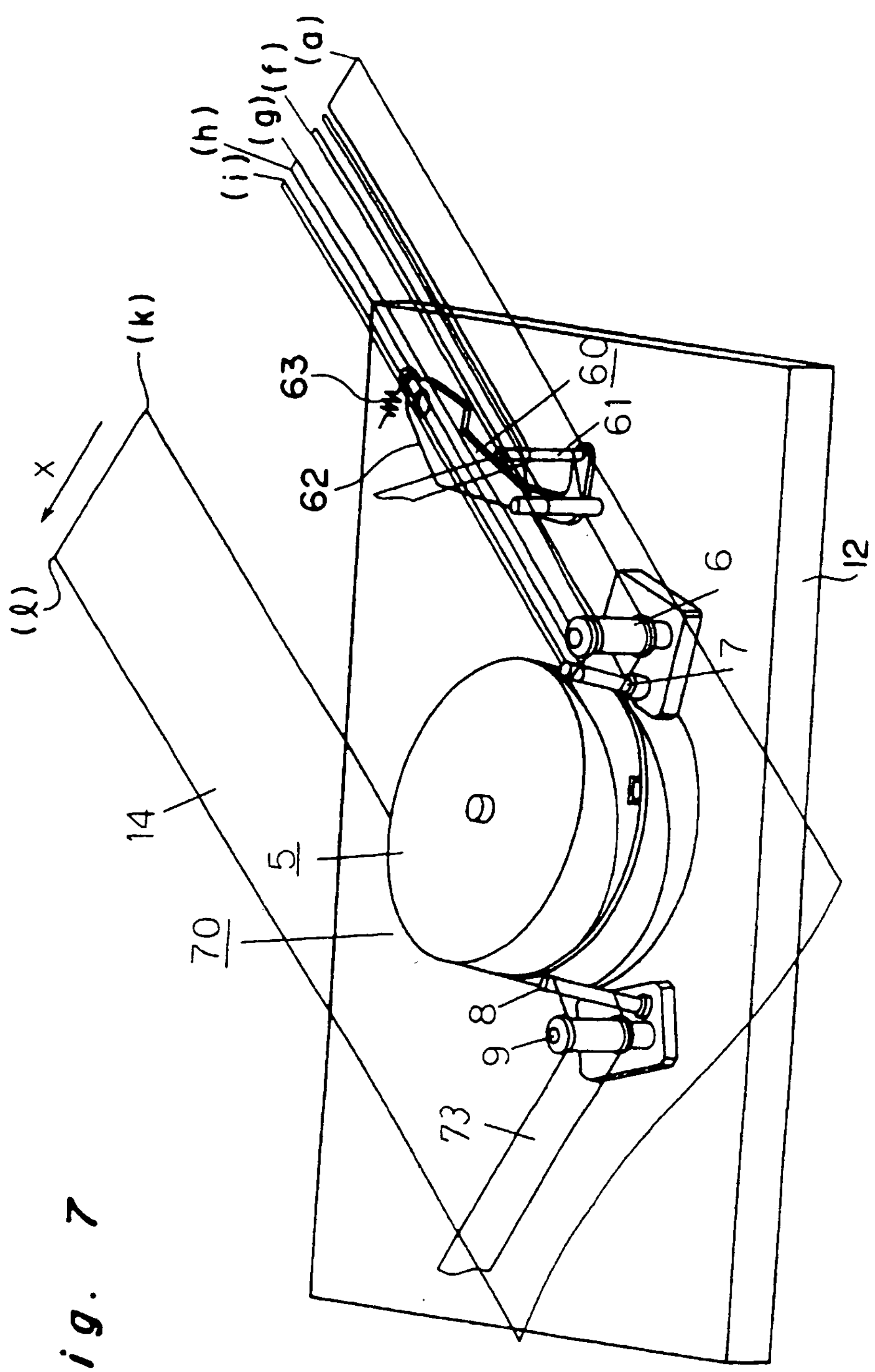
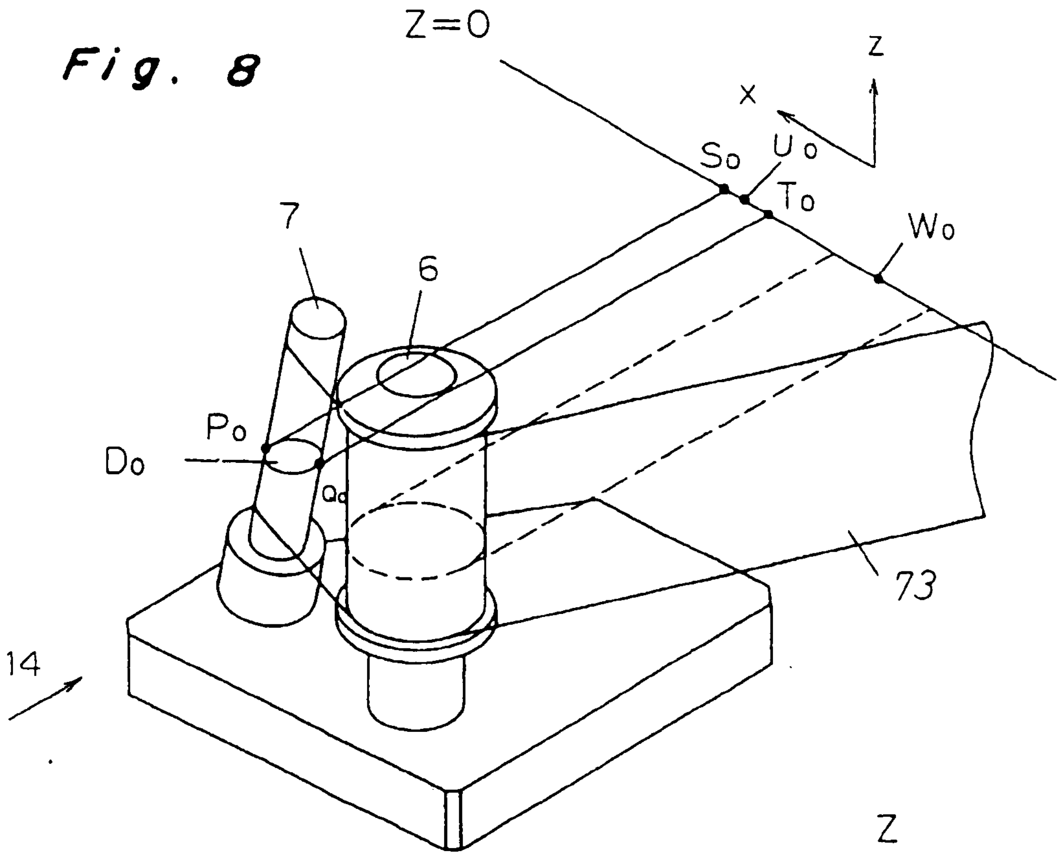


Fig. 7

Fig. 8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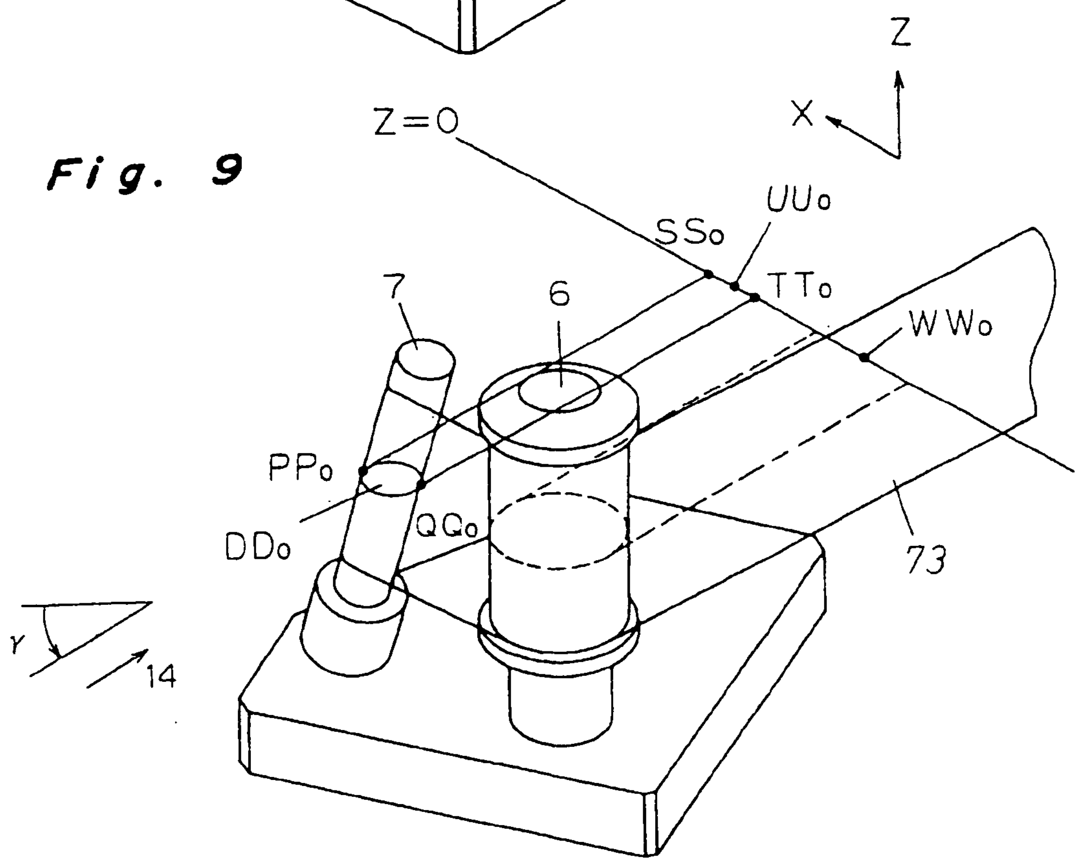
14

Fig. 9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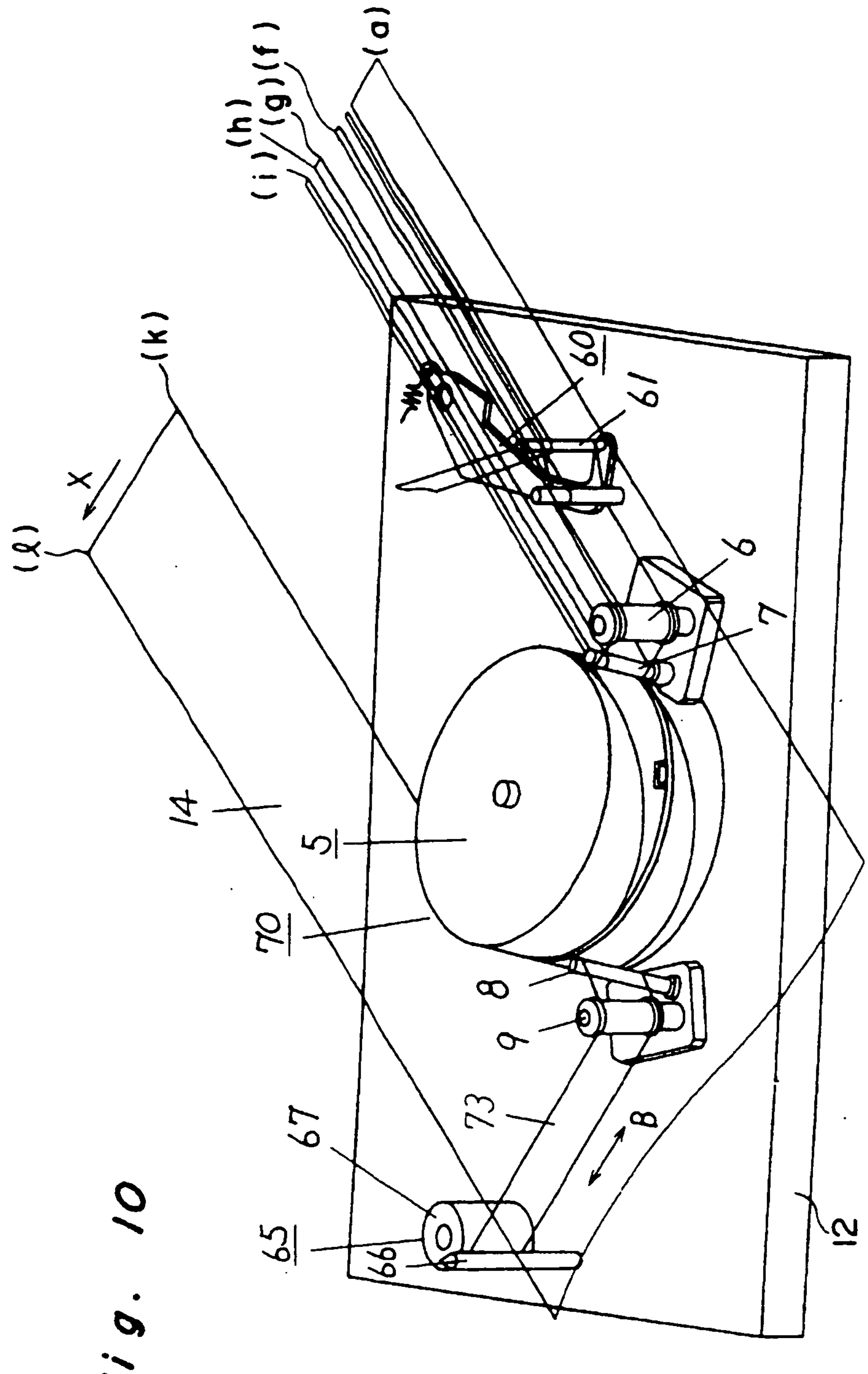

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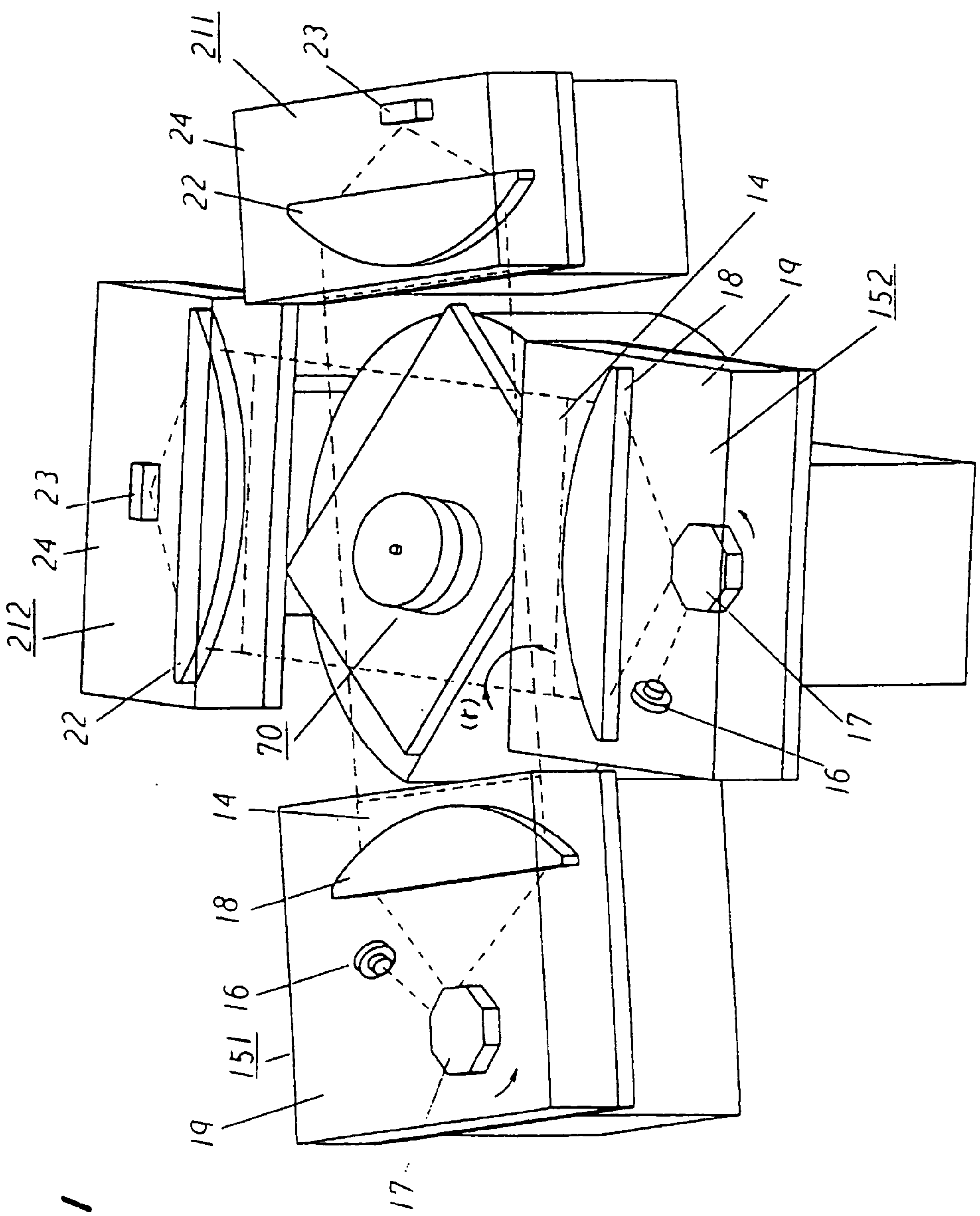

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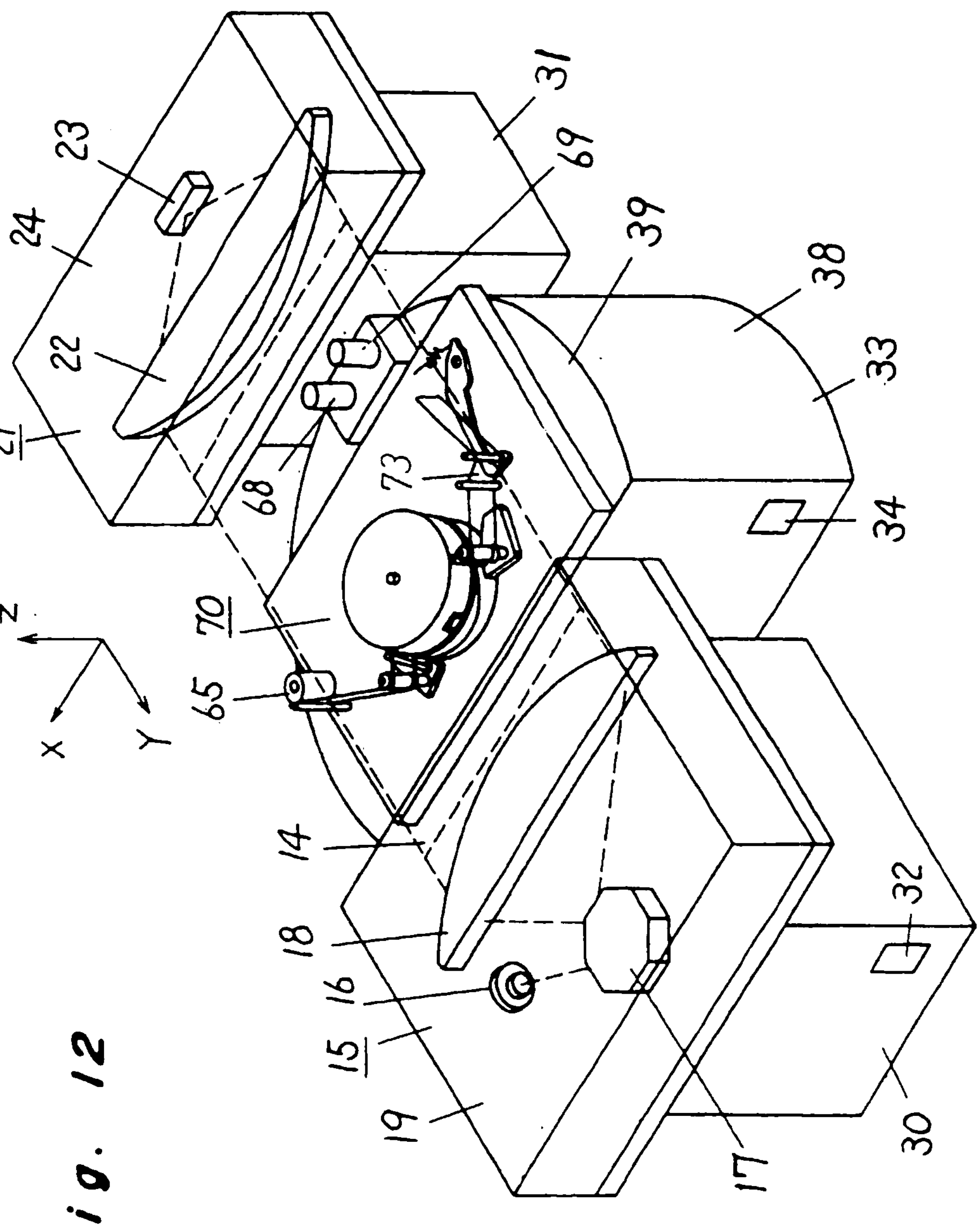
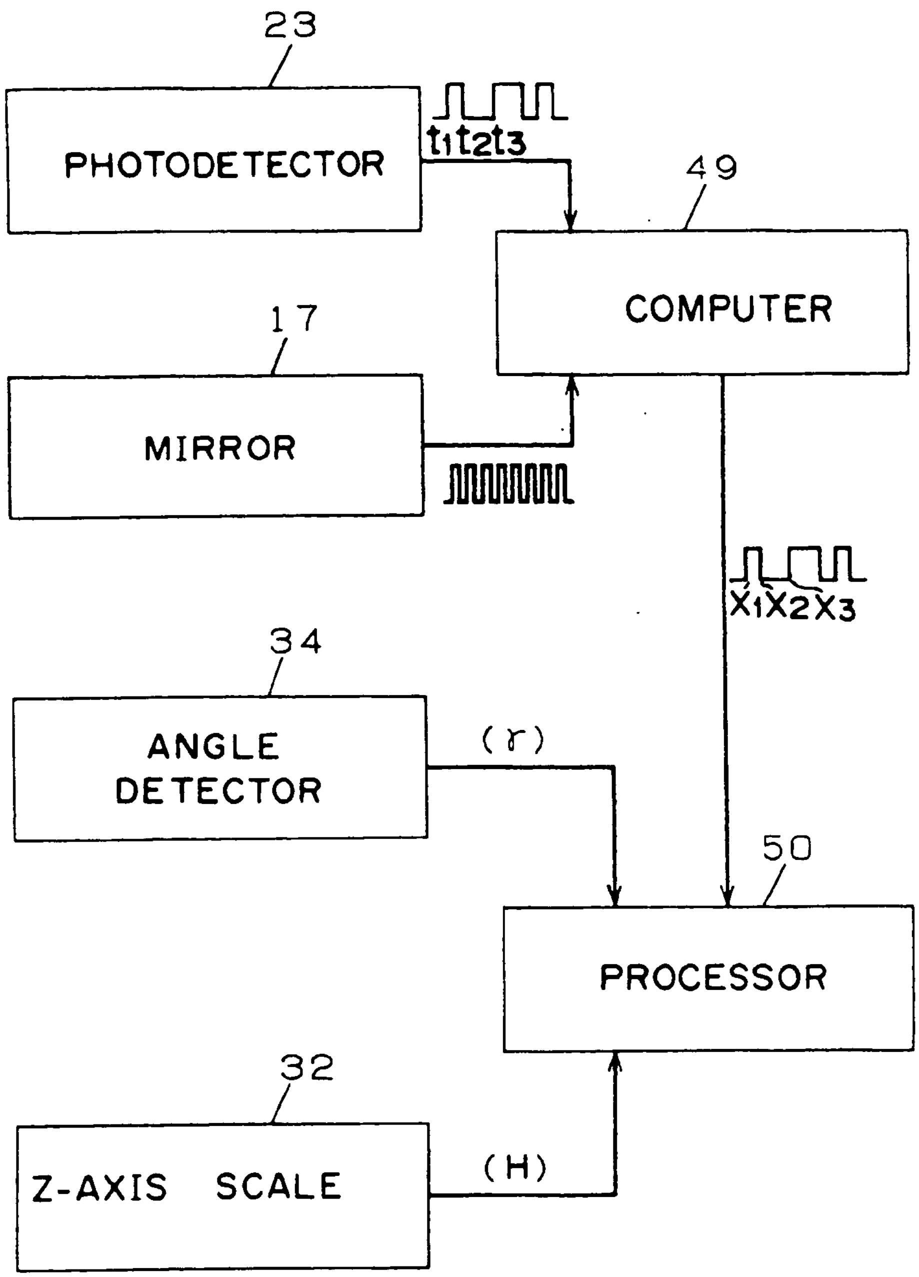


Fig. 12

Fig. 13


23
PHOTODETECTOR
t1t2t3
49
COMPUTER
17
MIRROR
X1X2X3
34
ANGLE
DETECTOR
(γ)
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PROCESSOR
32
Z-AXIS SCALE
(H)

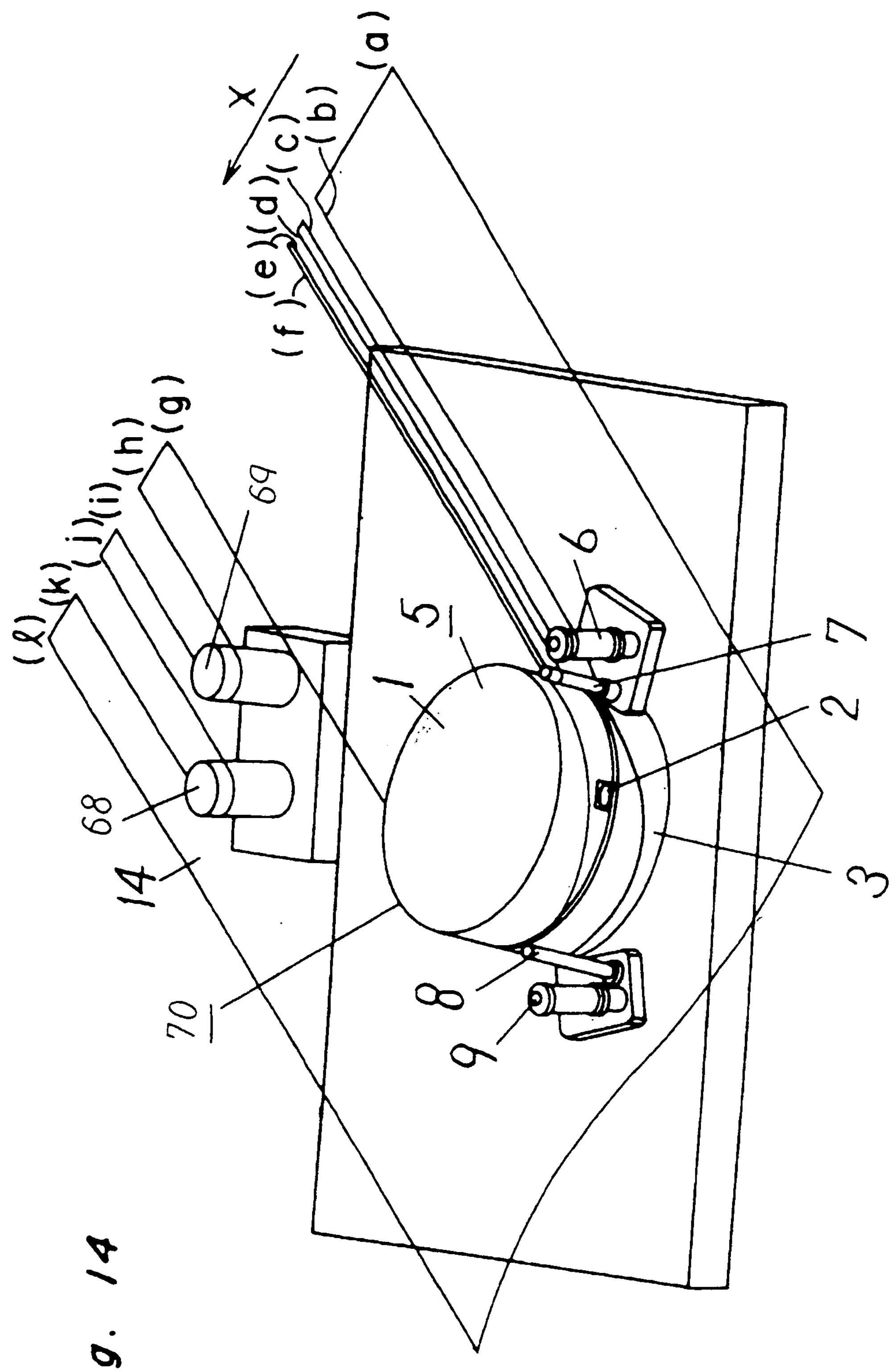

Fig. 14

Fig. 15

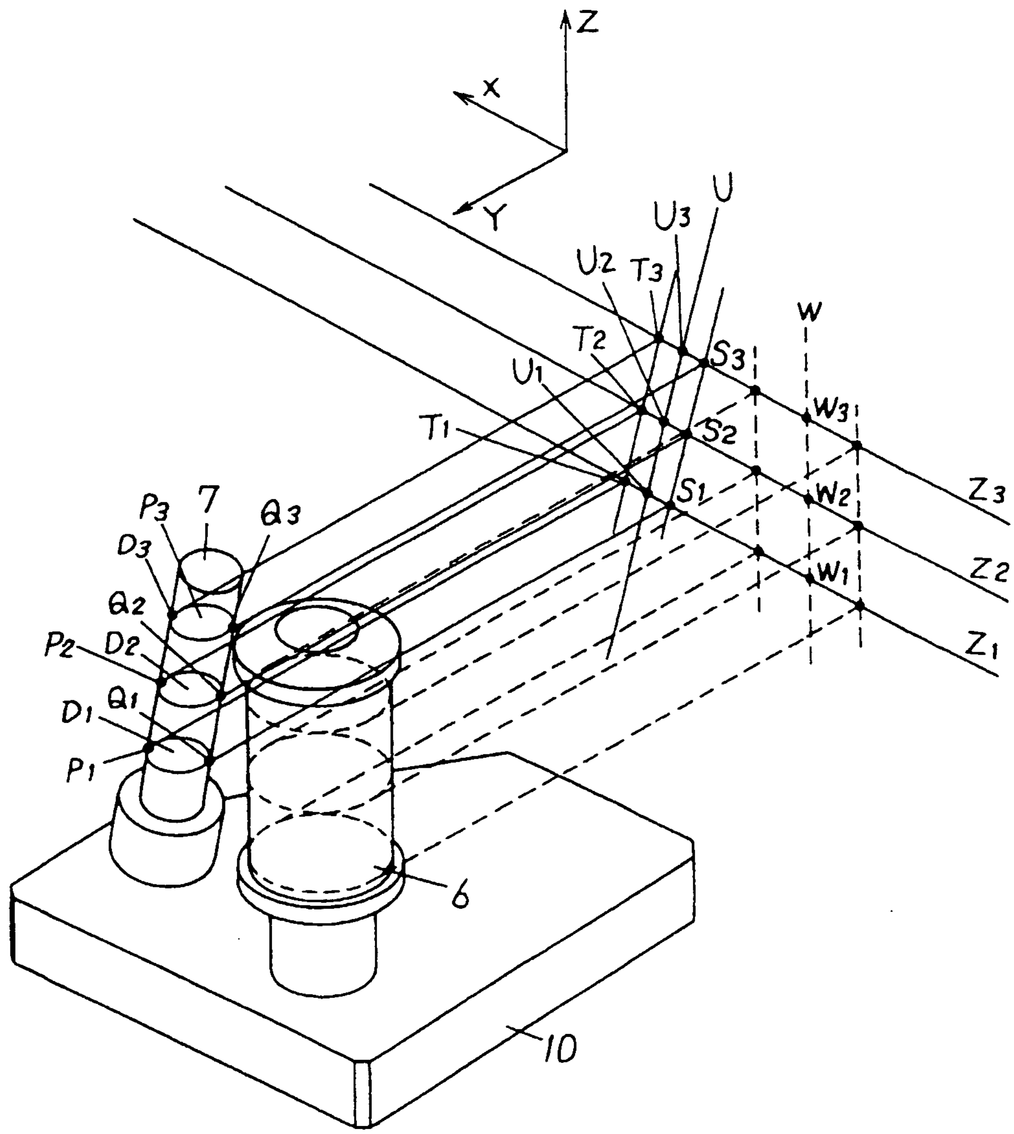
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Fig. 16

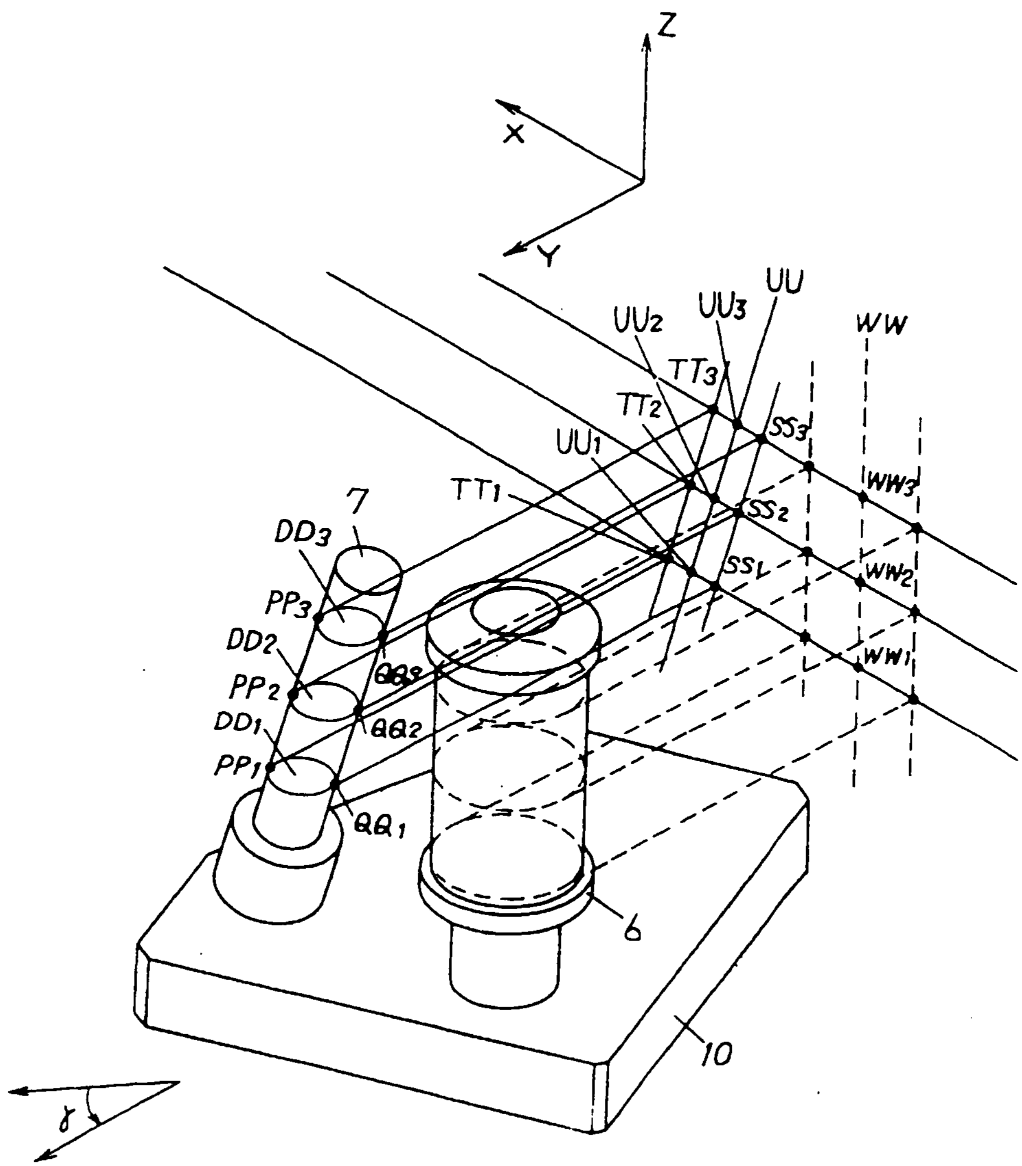
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Fig. 17

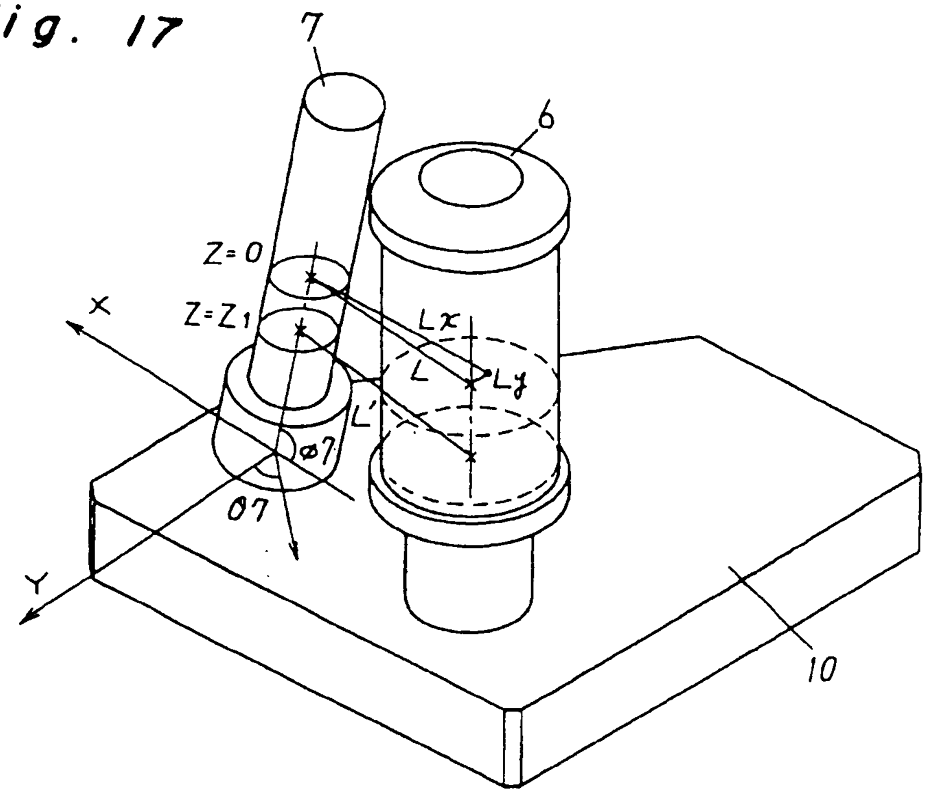
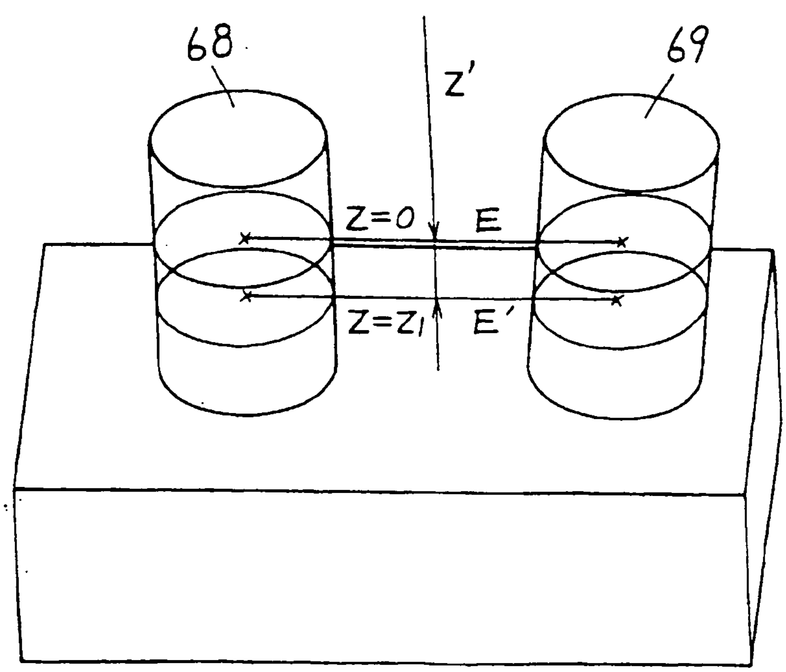


Fig. 18



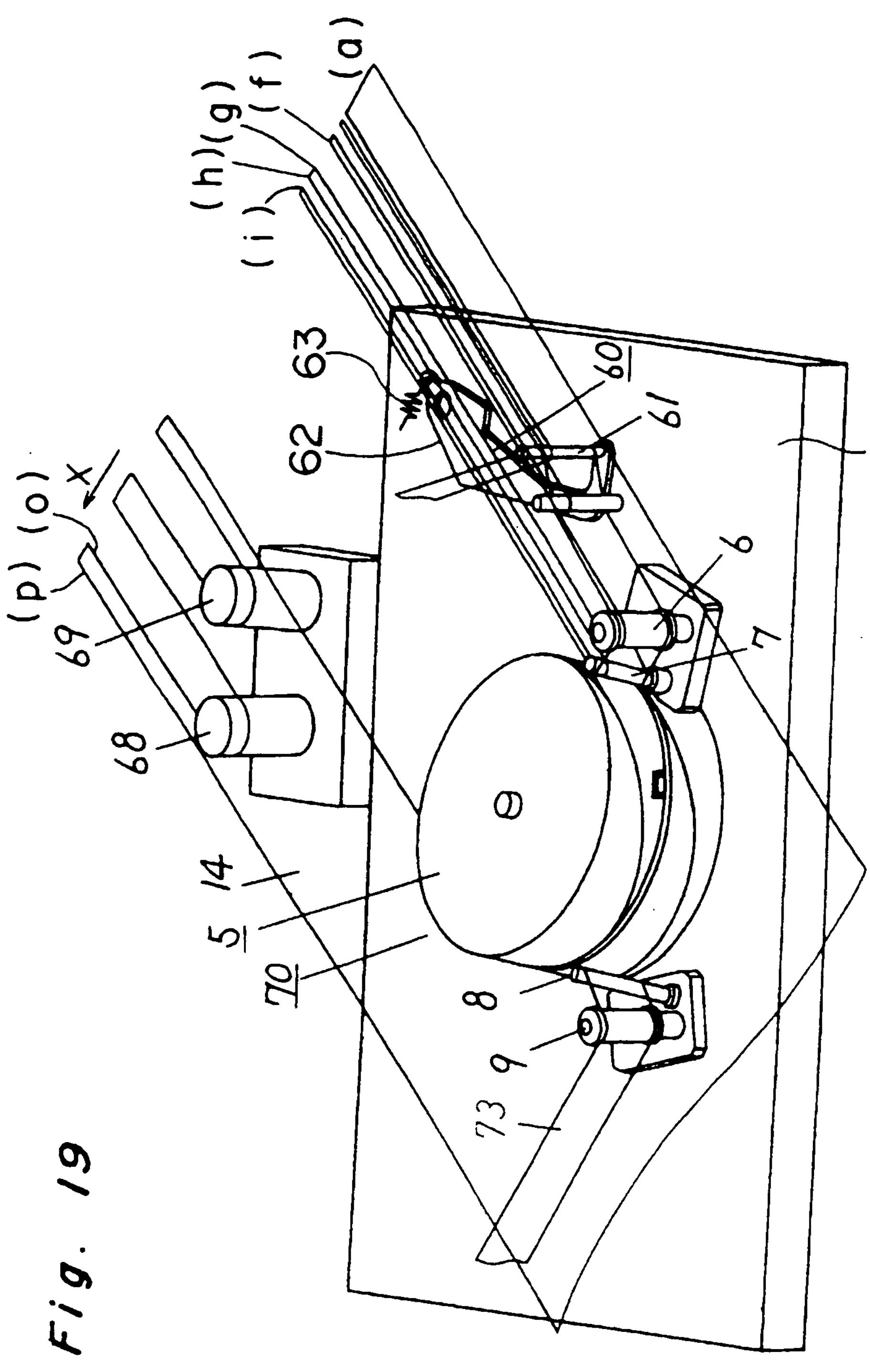


Fig. 19

Fig. 20

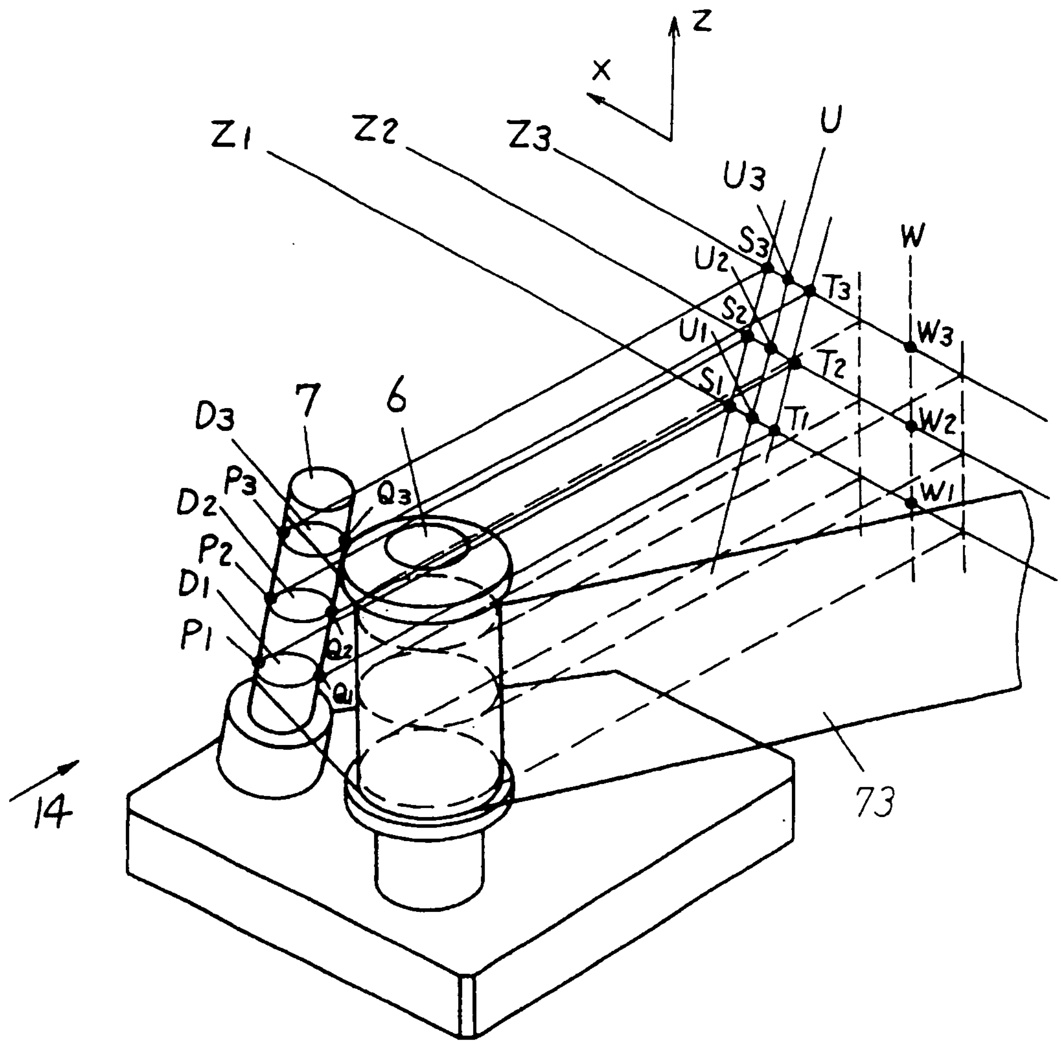

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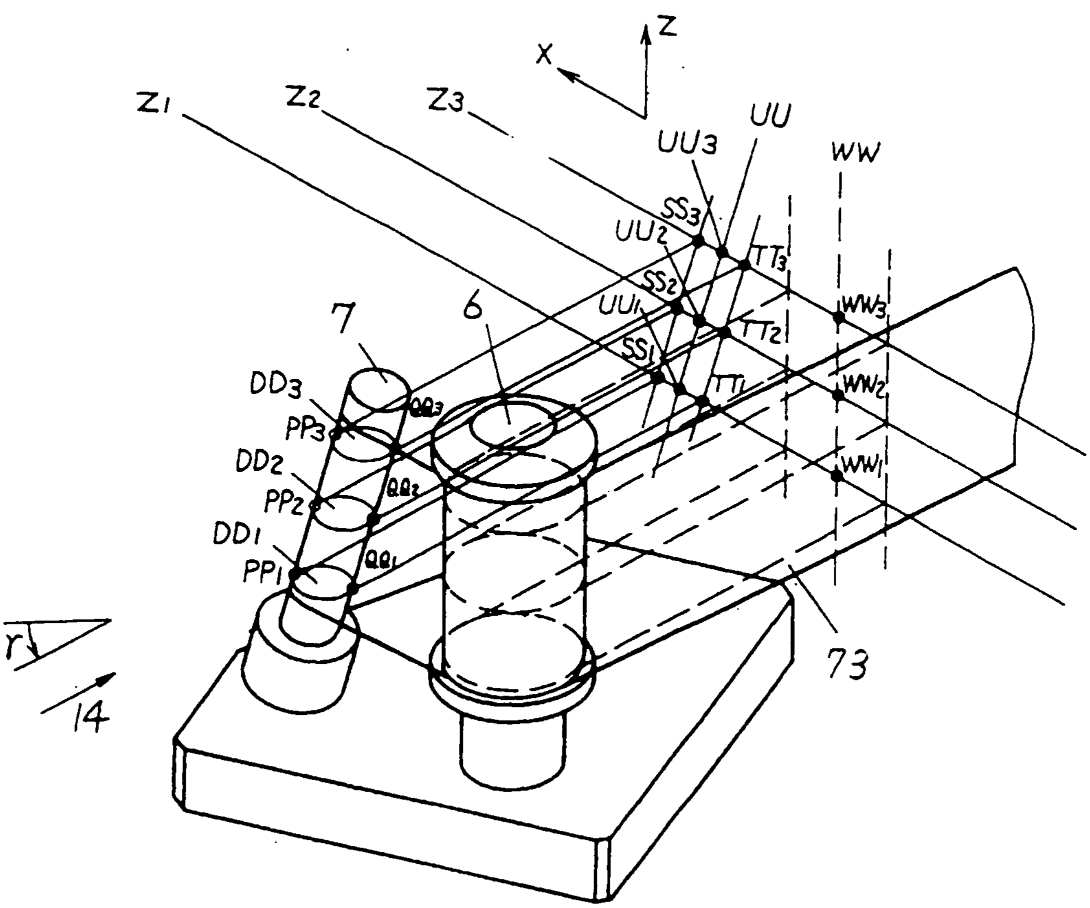
Fig. 21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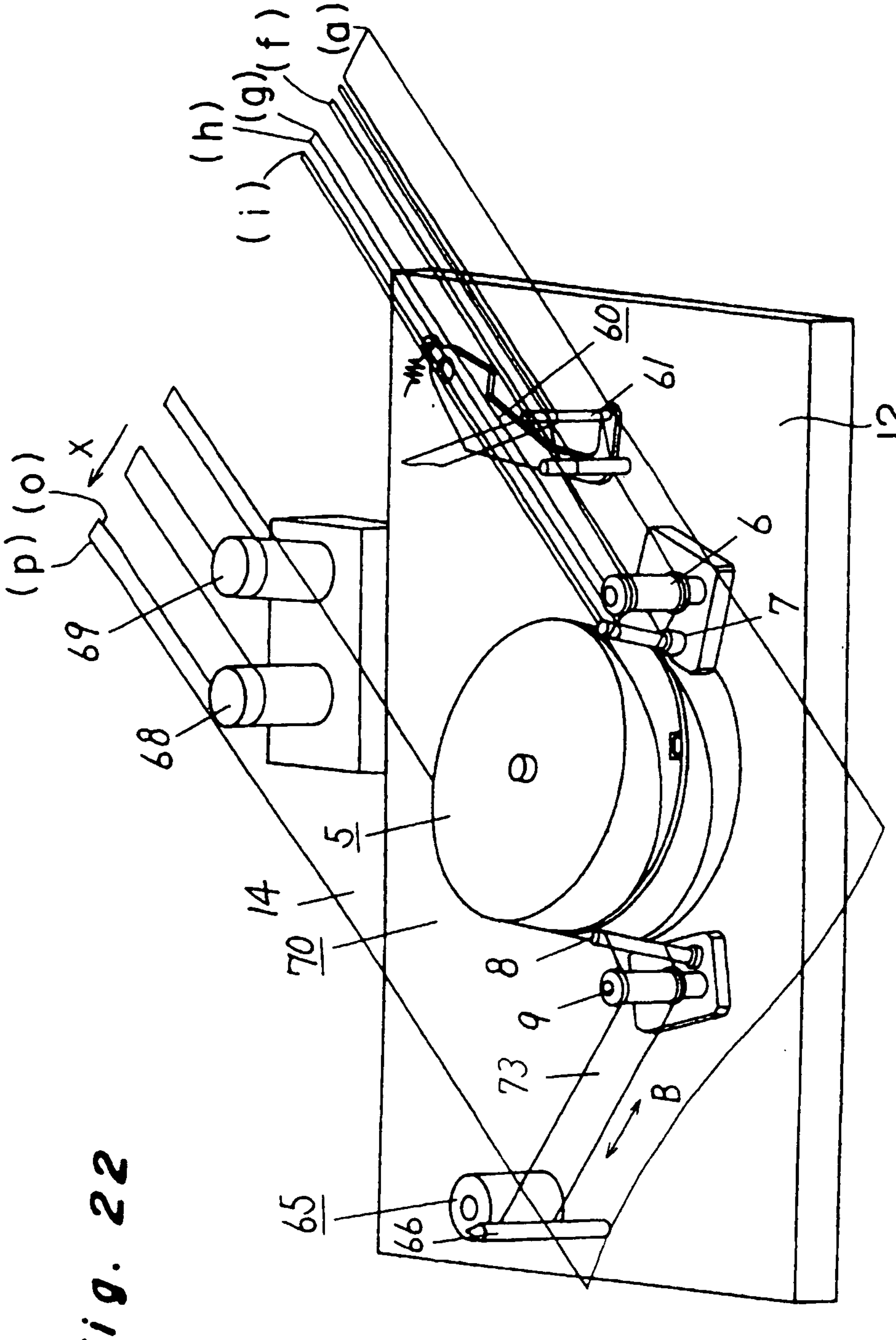

Fig. 22

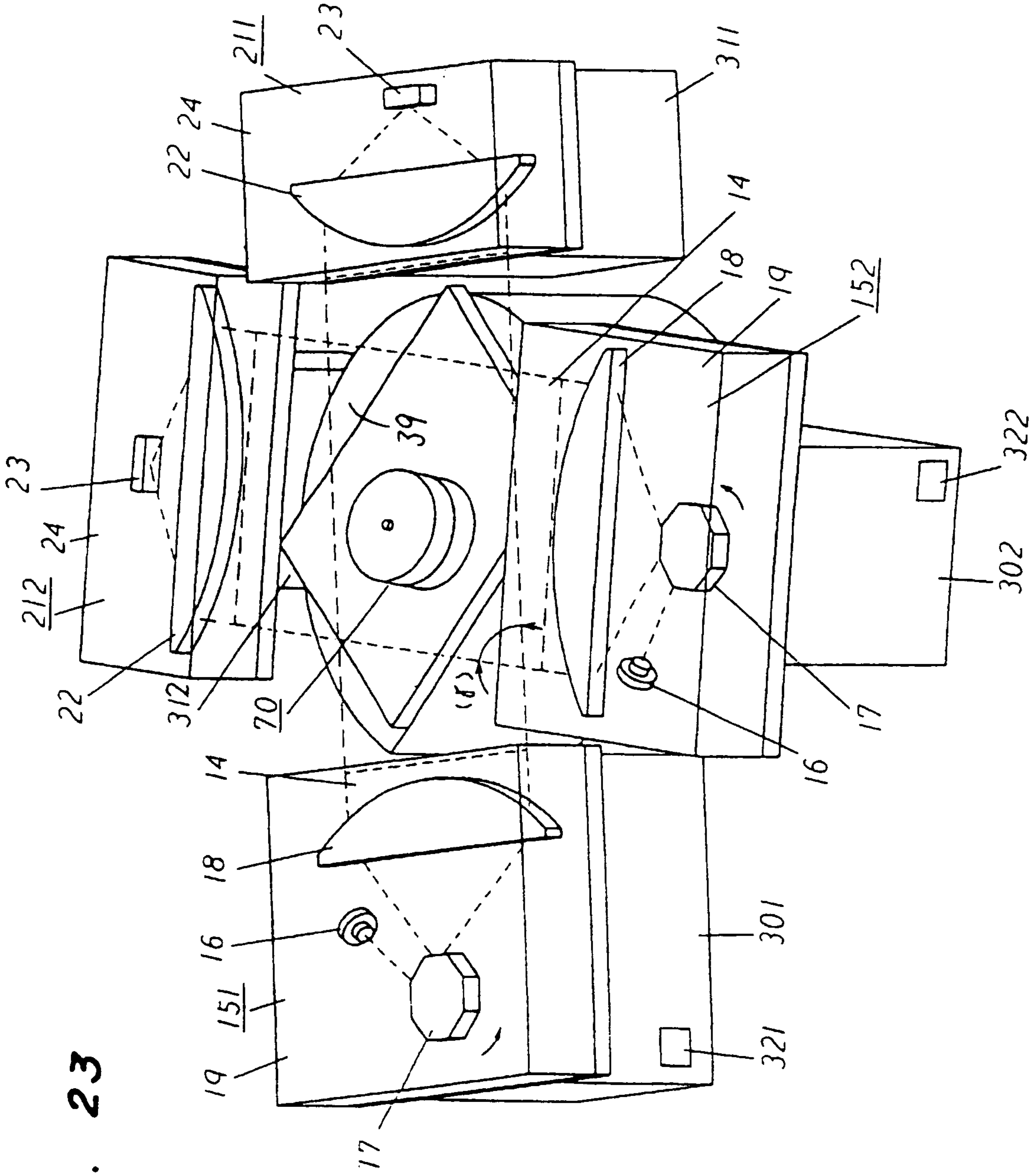
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Fig. 23